The Management of Risks In International Infrastructural Projects

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DEDICATION

To my two sons, Kweku Jehoiada Takyi-Nyameye and Joel Selasie Kojo Adams.

DECLARATION

This thesis is the result of research studies undertaken in the Department of Business Studies at The University of Edinburgh for the degree of Doctor of Philosophy.

I declare that all the work in this thesis has been carried out by me unless otherwise stated, that this thesis has been composed by myself and that this work has not been submitted for any other degree or professional qualification except as specified above.

Francis Kofi Adams
June, 2004

ABSTRACT

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In spite of the nature of construction contract risks, the variability involved in their outcomes and the potential benefits that applying rigorous and probabilistic approaches offers the analysis of such risks, existing predominant practices continue to involve the use of risk assessment and analysis approaches that are often arbitrary, illogical, inadequate, misleading and subject to considerable personal perceptions and biases of the "solo" analyst. The lack of rigour and systematic approach is often blamed on the possible high cost of pursuing a rigorous process and the unavailability of relative frequency data on the separate risks. The practice of using lump sum or percentage contingency, individual approaches to risk analysis and at best three-point or triangular distributions for risk analysis have thus persisted even though evidence from other industries suggests that rigorous and probabilistic approaches could be applied to construction contract risks.

This thesis aims to conduct a review and survey to establish the appropriateness of the types of risk management techniques currently used in the construction industry, to investigate risk perception in construction and its impact on project performance, and to develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception on individual estimates of risk, and provides these opinions as input variables to the rigorous and probabilistic analysis of contractual risks. The work is a cross-cultural study, applying mail questionnaire surveys, interviews, Delphi and Vignette techniques, and analyzing risk management approaches and applications of the elicitation model developed by the study in both United Kingdom and Ghana. The data generated by the elicitation model are analysed using relative likelihood methods to develop subjective prior probability distributions for use as input variables in the Bayesian analysis of contractual risks in construction.

The study concludes that although relative frequency data are often unavailable for contractual risks, existing predominant practices for contractual risk analysis are inappropriate for the nature of contractual risks. Furthermore, individual perceptions about risks significantly affect expert judgements about risks (and consequently project performance) in spite of their expertise. Using the expert elicitation model developed by the study and the analytical approaches applied, it is possible to capture, encode and aggregate the knowledge and experiences of a group of relevant experts to derive probability distribution functions of contractual risks to be applied as input variables to a Bayesian analysis of contractual risks, and thereby achieve a more appropriate, systematic and rigorous approach to contractual risk analysis. Evidence from the study also indicates that this approach need not involve any significantly high costs as the analysis can be done using standard spreadsheet software and add-in programmes that companies already have on their computer systems.

Recommendations are thus made for the use of expert team approaches and the elicitation model developed in the study in the management of contractual risks. In addition, implications on existing types of contract, risk management education and further research are highlighted.

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CHAPTER 1

INTRODUCTION

1.0 Risk: It is a fact of life!

Life is full of uncertainties. The only events that are known with full certainty are those that have already happened. Even those who are gifted with the powers of prediction such as Prophets, often have great difficulties predicting the future with total clarity. Yet most personal and business decision-making are of necessity made in the context of *uncertainties* and *expectations* about the future. Making decisions on the basis of assumptions, expectations, estimates and forecasts of future events involve taking risks, and neither man nor any human organisation can survive without taking risks. Risks pervade all human activity. In many respects therefore, everyone has a level of expertise in risk and thus has a valid contribution to make in developing a fuller understanding of the subject of risk.

The development of our awareness and handling of risks starts from infancy. The entire process by which we learn to crawl, walk, talk or ride a bike involves decision-making in the face of uncertainties. Decisions made in these circumstances usually involve arriving at some acceptable balance between expected rewards arising from taking a defined action, against the perceived cost or pain of failure. We are trained by our parents and guardians in risks and sensitised by them not only to the nature of risk-taking and risk management, but also in the levels of responsibility for risk management within the human society. For example, while children take the risk in learning to walk and enjoying the full potential of their legs, parents or guardians take natural and often legal responsibility for ensuring that this is done safely. Hence, parents would sometimes caution the child: Do not run; you will skin your knees! Furthermore, we become aware of the role of higher authorities in the risk management process by observing how other people or governmental authorities take action against abusive or negligent parents or guardians who fail in their responsibilities towards the safety of the child. We seem to enjoy the simplicity and adventure in risk taking as children. As we grow to adults, though, the world becomes more complex and confusing!

The environment in which business decision-making takes place is also characterised by risky and uncertain circumstances brought about by a dynamic mix of controllable and uncontrollable factors. The decision-making environment in the construction industry is not exempt from such factors. In fact, the construction industry is subject to more risks and uncertainties than many other similar industries! The process of developing a project from basic ideas and mental concepts through feasibility studies, architectural and engineering design, procurement, construction and commissioning to maintenance is not only complex, but involves myriad people of diverse backgrounds, skills and aspirations brought together to achieve a common goal - the project. When one considers the compounding effect on such complexity of other factors such as political, environmental and economic situations that are often totally outside the direct control of the project parties, then the need for the systematic management of project risks towards achieving desired project goals become self-evident.

Recognising the existence of such uncertainties and risks in a project is only part of the total risk management process. Assigning the appropriate interpretations to the nature and impact of the risks and uncertainties on the project is another part of the risk management process that has a significant impact on the effectiveness of the risk management effort. Herein then lies another complication in dealing with risks, particularly construction risks: how people perceive risks. With the exception of risk situations where an assessment of the full nature of the risk can be made from carefully and fully documented data, the individual risk assessor's *perceptions* of the nature, likelihood of occurrence and possible impact of a risk greatly influence the outcome of any risk management effort. Perceptions arise from the person's knowledge and experiences, and can thus be as varied with regard to the same risk as there are people who need to deal with the risk! Sunstein (2002) argue that people's judgements about risks can go badly wrong due, among other facts, to the fact that they often lack adequate risk-related information. Kendrick (2003) thus discusses the need to aggregate individual views about risks in developing an effective project management approach. Thus, an important issue in ensuring optimum effectiveness in the management of those risks for which adequate historical data are not available is the management of the perceptions of the people who are involved in the risk management effort.

1.1 Dealing with Risks in Construction Contracts

Risks in construction stem not only from financial aspects of the project such as the variability in the costs of the materials used but also from the technology of the materials and methods used and other factors such as weather conditions, labour disputes, political developments etc. These present different types of risks that require different approaches for their systematic management. Historical data coupled with some form of statistical analysis may be useful in assessing the financial/economic risks in a project and the reliability of any technology applied in the project. However, data on risks such as weather conditions, disputes etc., tend to be either insufficient or too imprecise to enable any reliable application of statistical analysis of such risks. Therefore, assessments of these types of risks tend to be subjective and generally very informal and unsystematic. They are often the main subject matter of any construction contract and come under the broad category of risks referred to in this study and elsewhere as contractual risks.

The term "contractual" is used here to categorise such risks mainly because they arise out of the manner in which risks are distributed through the contractual relationship among the project parties (Rubin & Wordes, 1998). They are thus the types of risks about which the construction "contract" is mainly concerned. They are often about the unexpected, or those things that it is hoped will not happen at all; however, if they do, then someone will have to bear the cost associated with their occurrence. For example, labour disputes generate a construction risk that has a potential for delayed project completion and escalated project costs. It is hoped that such a risk will not occur, but if it does, someone has to bear the extra costs or losses caused by extra administrative activities, delayed project revenue, and other remedial activities. Labour dispute thus constitute a contractual risk to a project.

Contractual risks can be differentiated from financial or economic risks in that financial/economic risks involve costs that are "intended" to be incurred, but the risks lie only in the uncertainty of the degree or amount of expenditure. In terms of the financing of a housing construction project for example, it is "intended" that expenditure be made for procuring appropriate materials for the project. Financial risks arise due to the range of possible project costs (range of material quantities and prices during the duration of the project) each of which has a certain probability of occurring. Risk management in this context is concerned with identifying the range of likely values each potential result may have, analysing them and responding to them to develop a rational and most efficient project management approach (Murdoch & Hughes, 1992). Furthermore, the relative availability of pricing, economic and design data on the components of such costs allows the application of statistical analysis to such risks.

The similarity between contractual risks and economics risks lies in the fact that they are both concerned with the eventual payment of, and responsibility for costs associated with construction (Murdoch & Hughes, 1992).

Formal risk management processes have been applied in various ways to the determination and management of the financial or economic risks inherent in construction projects at the early stages of project development (Pouliquen, 1970; Chapman, 1979; Perry & Hayes, 1986; Cooper & Chapman, 1987; Ranasinghe & Russell, 1992; Flanagan & Norman, 1993). In spite of the potential benefits that the application of similar rigorous and systematic approaches will offer a broader spectrum of construction projects risks, there is very little literature or guidance on the application of such processes to the management of the contractual risks inherent in construction projects (Chapman, 1991). The lack of rigour and systematic approach is often blamed not only on the extra cost of pursuing a rigorous and systematic process (Simister, 1994), but also on the unavailability of relative frequency data on the separate risks, particularly to individual companies (Wright & Ayton, 1987). The predominant industrial practice involves the use of standard forms of contracts which allocate standard contractual risks to the parties involved, particularly the contractor(s) and the client.

Hayes *et al.* (1986) reported that contractors hardly assess the separate risks that they are asked to carry, but resort to the addition of a single percentage cost contingency to give an overall impression of their perception of the total risks that they are asked to carry. One of the problems with this approach is that the perception of the contractors regarding the project risks strongly determines the reward or premium that they ask for as compensation taking the risks (Slovic *et al.*, 1970). This percentage cost contingency is often also chosen arbitrarily and tends to direct attention away from other project risk targets such as project duration (Hayes et al, 1986). Mok *et al* (1997) argue: "such an approach is illogical, as risks are not separately identified for evaluation, and the allowances are often too high for low-risk projects or too low for high-risk projects.

Moreover, the approach is cost ineffective and reactionary in nature because as the project is progressing from feasibility stage to tender stage, many of the risks become known and some can be eliminated. Therefore the allowances made for these known risks and eliminated risks should be suitably adjusted so that efforts can concentrate on the unresolved risks". Other research such as the analysis of contractors' approaches to risk identification in Australia (Bajaj *et. al.*, 1997) also suggests that predominant practices are *top-down* approaches in which projects risks are analysed from an overall project view rather than on individual risk basis. Bajaj *et. al.* (1997) argue that top-down approaches lead to guesswork in regarding the contingency for risks accepted by contractors. Burchett *et. al.* (1999) in their world-wide survey of risk management practices within electrical supply projects confirmed a global drive towards a more thorough assessment of risk and argued that a formal risk management process is more likely to apply to large complex projects with the potential for cost overrun. The study however also argued that the criteria for application are more likely to depend on overcoming managers' concerns about the time involvement, human and organisational resistance and understanding of the quantitative techniques applied in risk analysis. The recent increasing trends in UK and European project procurement systems towards mixed packaging and transfer/sharing of risks as seen in Finance-Design-Build-Operate-Maintain (FDBOM) contracts and Private Finance Initiatives (PFI) also only highlight the need for a comprehensive and systematic approach to risk management (ICE *et. al.*, 1998).

The guidance given by the Construction Industry Advisory Committee on designing for health and safety in construction promotes the adopting of qualitative assessment of risk frequency and severity (CONIAC, 1995). Within CONIACs guidelines, risk frequency and severity at a very basic level can be classified as low (up to 5% chance of occurrence), medium (about 50% chance of occurrence) or high (over 75% chance of occurrence). The fact that this guidance, which is considered by many as inadequate as a rigorous approach, is the latest and the current industry standard is an indication of the need facing the industry. Batty (1996) concluded in his study of risk in engineering design that it is possible to develop and adopt a relatively easy, inexpensive and yet systematic and rigorous approach to risk estimation in engineering design. However, as with earlier studies, Batty's study paid little attention to the effect of perception in the initial subjective estimates provided by the engineering experts for the risk analysis exercise. The use of ERA (Estimating using Risk Analysis) and MERA (Multiple Estimating using

Risk Analysis) have also been advocated for use in the industry (Mak, *et al.*, 1998). The PRAM (Project Risk Analysis and Management) and RAMP (Risk Analysis and Management for Projects) methods were also recently introduced respectively by the Association of Project Management (Chapman, 1997) and the team effort of The Institution of Civil Engineers and the Faculty and Institute of Actuaries (ICE *et. al.*, 1998). While all these methods offer major improvements over the arbitrary contingency sum approach, they do not deal adequately with the effect of perception on the subjective estimates used in these analytical approaches.

The use of subjective probabilities to describe the uncertainties associated with input variable values for economic risk analysis has been very well reported in the literature (Pouliquen, 1970; Bjornsson, 1977; Perry & Hayes, 1985; Cooper & Chapman, 1987; Ranasinghe, 1990; etc.). Ranasinghe and Russell (1993) also successfully applied a Delphi-style interviewing technique to elicit expert knowledge as accurate, calibrated and coherent subjective probabilities for use as input to economic risk analysis. These studies however, all tackled economic risks without considering the peculiar nature of contractual risks. The application of systematic and rigorous methods to contractual risk is rather scant, and there is very little reported on empirical work on the elicitation of subjective probabilities for contractual risk analysis in the literature. However, applications and work of this nature in other industries can only point to the enormous potential that such methods present to the construction industry. For example, in addition to the use of classical methods of objective probability forecasting in short-range weather forecasting, subjective probability forecasting is used generally reliably in meteorology (Murphy and Winkler, 1984). Dey (2002) also successfully combined subjective estimates with objective data in managing risks in a hydrocarbon processing (refinery) construction project. Elicitation of expert beliefs/information has been used in the development of probabilistic expert systems for the diagnosis of congenital heart disease (Spiegelhalter *et. al.*, 1994), and in population projection (Daponte *et. al.*, 1995; and Kadane & Wolfson, 1997). Elicitation of prior beliefs have also been successfully used in estimating the future maintenance costs of water treatment plants, in determining the hydraulic conductivity of rocks for nuclear waste repository development (O'Hagan, 1997), and in uncertainty analysis for radiological protection (O'Hagan and Haylock, 1996). Pattillo (1998) also successfully used elicited subjective probability distribution over future demand for Ghanaian manufacturing firms' products to construct expected variance of demand which was used as a measure of uncertainty in investment decision making by Ghanaian entrepreneurs.

The need for a systematic approach to risk management and the effect of the project parties' perception of project risks on project outcomes come into even sharper focus when construction firms have to work overseas on international projects. International contracts introduce new complexities into construction project risks. Companies undertaking international projects not only have to deal with the risks associated directly with the development of the project but also with cross-cultural, political, social and other such factors. These generate risks that they may not be very knowledgeable about, but which have major impact on project estimates, management and success. Beliefs, opinions and perceptions which underpin most decision-making in one country may need to change when operating in another country and culture, if the desired project objectives are to be achieved! Cullivan (1981) suggests that the allowance for risk made by a UK contractor working overseas is often the largest single item of cost in his tender. In their study on cultural diversity within psychological research and theory, Li & Karakowsky (2001) concluded that people with different cultural backgrounds may view the same phenomenon in different ways, and that "the cultural or behavioural preferences of observers from different countries or cultures may lead to different assessment results, even though these observers may have actually observed the same behaviour". Failure to acknowledge these differences can lead to biased decision-making information and consequently poor-quality of management decisions. The author's personal experience in working in both Ghana and the United Kingdom suggests that such high allowances for overseas project risks is a consequence of the UK contractor's perception of the risks associated with the overseas project, rather than the real risk in the overseas country.

1.2 Risk management practices, subjective probabilities and expert elicitation

The previous section made references to a number of research studies in the area of risk analysis and management that have relevance for the current research. It also pointed to applications of subjective probabilities and elicitation of expert beliefs in other industries which provide basis for investigating similar applications to contractual risks. Some of these prior research studies and applications are discussed in this section to illustrate the similarity of the risks studied to the risks being studied in the current research and highlight lessons from those studies and applications that would be of benefit to the current research.

(a) Analysis of contractors' approaches to risk identification in Australia

The study by Bajaj *et. al.* (1997) of contractors' approaches to risk identification was aimed, among other objectives, at identifying, investigating and evaluating the approach of building contractors in New South Wales, Australia, to the process of risk identification during the tendering and estimating stage, and the risk identification techniques used by the contractors. The study which adopted a mixed methodology of questionnaire and interview surveys targeted the Chief Estimators of 19 construction contractors in the region. The survey methodology can be summarised as follows:

(i) Selection of contracting companies from the region's Yellow Pages telephone directory.
(ii) Initial phone calls to the chief estimators of the companies select to establish their willingness and commitment to participate in the research.
(iii) Mailing of questionnaires to participants who had agreed to participate
(iv) Setting up of appointments for face-to-face interviews with participants
(v) Face-to-face interviews with participants to obtain responses to a number of questions on the standardised questionnaire

In analysing the approach to risk identification, the study sought responses to five approaches: *risk review* (an internal review of all the different sources of risk by senior staff of the contracting company, the number of staff dependent on project size), *contact* (discussions with client team and architect on project requirements, and with subcontractors on pricing issues and specific difficulties), *research* (research on specialised trades for trade-specific information, analysis of the industrial and economic climate, etc), *site visit* (visit to the site to review potential problems areas such as traffic and access to site, obstructions, location, etc.) *and finance* (a review of the financial status and guarantee of the client, project funding and the amount of security for guarantee by the contractor). Overlaps exists in the definitions of the types of risk identification approaches used in the survey, and although the authors failed to clarify how they arrived at such a classification, they nevertheless identified risk review as the predominant approach to risk identification (about 68% of respondents used this approach). The study also found that the review was usually done by 1 or two experienced senior staff in the company (over 84% of respondents used this approach). On techniques for risk identification, the study found that the majority of respondents used top-down techniques such as case-based (about 79% of respondents) or aggregate or bottom-line (over 63% of respondents) approaches, as opposed to bottom-up techniques such as questionnaire and checklists or scenario analysis.

While the list of risk identification approaches and techniques surveyed were not very comprehensive and distinctive in their definitions, the survey methodology was nevertheless effective in achieving the objectives of the survey, and provides good guidance for the design of the current research. Furthermore, the results were consistent with the findings of prior research conducted in the UK by Simister (1994).

(b) Survey of risk management practices within electrical supply projects

The study by Burchett *et. al.* (1999) aimed at examining the world-wide practices and trends regarding the use of risk management methods in capital budgeting in electrical utility supply companies. Specifically, the study examined the extent of risk identification done, the methods of risk measurement and assessment, the risks adjustment methods used for project evaluation, the reasons for using risk management techniques, the changes in the use of the risks management process, the attitudes towards the use of a formal risk management process (RMP), the perceived benefits of their use, the barriers faced in their use and the level satisfaction with the use of RMP. The study adopted a standardised mail questionnaire approach. The survey methodology can be summarised as follows:

(i) Determination of survey items by establishing the extent of concerns, attitudes, applications and acceptance of risk analysis/management processes through a review of the literature.

(ii) Design of the survey instrument based on an instrument used for prior similar research by Ho and Pike (1989).

(iii) Pre-testing and revision of the survey instrument to obtain accurate results

(iv) Selection of about 140 senior managers of electric utility companies based on their interest and involvement/participation in prior questionnaire research in the electrical supply industry.

(v) Mailing of questionnaires to the 140 selected managers

(vi) Issue of reminders to non-responding managers.

(vii) Follow-up on non-responses to establish reasons for non-response.

Respondents express their answers using a 6-point likert scaling method adopted by the research. The analysis of responses based on this scale is used to determine, for example, the extent to which companies consider various risk factors in decision-making on capital investment projects. The extent of consideration is then used as a measure of the perceived frequency of the risk. On the methods of risk measurement and assessment used, the study concluded that sensitivity analysis was the predominant technique used (about 85% of respondents), followed by three-point estimates such as pessimistic, optimistic and most likely estimates (about 78% of respondents) and the subjective/intuitive assessments (low, medium, high) which was used by about 75% of respondents. Although probability analysis were used by about 62% of respondents, they only used them only a "little" on average. The study also uses correlation analysis on the risk measurement methods to ascertain the extent to which the methods are used by the electric utilities. The results confirm that the companies use a variety of methods on the same or different projects.

While the methodology of the study offered good guidance for the present research and the results were found to be consistent with the findings of the present research, the present believes that there is an implicit assumption in using the extent of consideration of risk factors in decision-making as a measure of the perceived frequency of the risk, that decision makers would consider more frequent risk in capital budgeting decisions more frequently. While the use of the likert scaling technique is helpful in assessing the extent of use or the relative frequencies of occurrences of risks in capital budgeting, it is not always the case that decision makers would consider more frequent risk more frequently in their decision making. For example, very frequent risks that have very little impact on the budgets may not engage the consideration of decision makers. Conversely, less frequent risks that have major impacts on budgets could cause decision makers to give serious consideration to those risks.

(c) Subjective probability forecasting in meteorology

Murphy and Winkler (1984) report that in the objective methods in meteorology, the specific forecasts produced for a particular procedure and a set of relevant data do not depend on a forecaster's judgement, although subjectivity is involved in the choice of a procedure and a set of data. In the subjective methods however, the formulation of the forecasts is based at least in part on the judgements of one or more forecasters. Where more than one forecaster is used, a consensus forecast is also found in addition to evaluating the individual forecasts. The consensus is found by combining the individual forecasts using either simple averaging of the individual forecasts (Sanders, 1979; Bosart, 1975) or various weighting schemes (Winkler, Murphy and Katz, 1977). Murphy and Winkler (1984) further report that the consensus schemes were found to perform better than almost all the individual forecasters. A number of features were also found with the subjective forecasts. First, the forecasts were found to be reliable in the sense that in forecasts about precipitation for example, the relative frequency of occurrence of precipitation on days with a subjective probability forecast of p tends to be very close to p. Also, in using measures of accuracy such as the Brier Scores in comparing subjective probability forecasts with climatology and with objective forecasting schemes such the MOS (i.e. measures of skill), improvements in Brier scores were generally made by subjective probability forecasts over objective MOS forecasts, especially for short-range or first-period forecasts.

One possible contributory factor to this improvement could be the fact that forecasters have access to the MOS forecasts (and other data that are not available at the time of preparing objective forecasts) to guide them in preparing their subjective probability forecasts. However, in the studies by Sanders (1973) in which he studied the forecasting skill of forecasters and found subjective probability forecasts to improve upon climatology by about 55%, 35%, 20%, and 10% respectively for one-, two-, three-, and four-day forecasts, no objective probability forecasts were available to the forecasters involved in the study.

Murphy and Winkler (1984) also attribute the successful use of subjective probabilities in meteorological forecasting to a number of factors. Among these are the sound physical and dynamical bases on which forecasting rests. Also since forecasting has always been considered a key part of meteorology, considerable time and effort has gone into developing, evaluating and improving forecasts, and hence developing forecasting expertise. Furthermore, similar meteorological events recur from time to time thereby enhancing the value of past data and experiences. Also, unlike applications in fields such as economics where forecasts can influence decisions that eventually affect the outcomes about which probability estimates were given, eventual outcomes in meteorological events are independent of the forecasts.

Despite these successes, Murphy and Winkler (1984) concede that a number of steps are needed for improving the process used by the forecaster in preparing subjective probability forecasts. They include the following:

(i) Provision of formal procedures to assist forecasters in quantifying their uncertainty in terms of probabilities
(ii) Training and motivating forecasters to improve their probability forecasts
(iii) Modelling the subjective probability forecasting process to isolate beneficial and detrimental steps
(iv) Adjusting subjective probability forecasts for known biases of known forecasters.

(d) Combining subjective estimates with objective data in refinery construction

Dey (2002) models a decision support system using risk analysis, based on the Analytical Hierarchy Process (AHP) developed by Saaty (1980) and decision tree analysis (DTA) , for making objective decisions on project planning, design engineering and resource deployment for a refinery construction project following project approval. It uses decision tree analysis (DTA) for selecting specific risk responses for specific work packages from various alternatives. The Analytical Hierarchy Process is a multi-criteria decision-making methodology that allows subjective as well as objective factors to be considered in project risk analysis. The methodology used in the risk analysis can be summarised as follows;

(i) Identify the work packages for risk analysis based on their importance in achieving project target
(ii) Identify the factors that affect the time, cost and quality of specific work packages through brainstorming sessions with experienced executives

(iii) Analyse their effect by deriving the likelihood of their occurrence using AHP
(iv) Determine the severity of the failure through subjective assessments
(v) Derive alternative responses for mitigating the effect of risk factors
(vi) Estimate the cost for each alternative
(vii) Determine the probability and severity of failure for a specific work package after specific response
(viii) Form a decision tree
(ix) Derive the Expected Monetary Value (EMV) or the cost of risk response
(x) Select the best response option through risk analysis

The AHP process involves the following three key steps. The first is problem formulation in terms of a hierarchy of decisions and decision options where the top level of the hierarchy reflects the focus of the decision problem; the intermediate levels reflect the elements affecting the decision and the lowest level of the hierarchy comprise the decision options. The next step is the prioritisation of the elements in each level of the hierarchy to determine their relative importance through pair-wise comparisons based on their importance in making the decision immediately above then and which is under consideration. The verbal scale used in the AHP (e.g., equally preferred, strongly preferred, very strongly preferred or extremely preferred) enables the incorporation of the decision-maker's subjectivity, experience and knowledge in an intuitive and natural way. These pair-wise comparisons lead to the creation of a number comparison matrices. This phase leads to the derivation of relative weight for the various elements of the hierarchy. The relative weights of the elements in each level of the hierarchy with respect to an element in the adjacent upper level are computed as the components of the normalised eigenvector associated with the largest eigenvalue of their comparison matrix. The composite weights of the decision alternatives are then determined by aggregating the weights through the hierarchy, by following a path from the top of the hierarchy to each alternative at the lowest level and multiplying the weights along each segment of the path. The result of the aggregation is a normalised vector of the overall weights of the options.

While the process incorporates the decision-maker's subjective judgement into the risk analysis process, the pair-wise comparisons and relative weights do not adequately describe the variability within the risk itself. Hence the outcomes that describe the risk are at best three-point estimates (low, medium or high) which assumes a triangular distribution for each risk under consideration. The results of the current research confirm that the distribution form for risks could vary with each risk and the assumption of the three-point estimates or the triangular distribution form for project risks is flawed.

(e) Eliciting subjective probabilities for economic risk analysis

The study by Ranasinghe and Russell (1993) investigated the human ability to predict future events using the decomposition of project activity duration and a technique for eliciting expert knowledge for economic risk analysis of construction project duration. The elicitation technique used, which is similar to that adopted by the present study consists of five phases:

(i) A pre-elicitation phase during which the expert is trained by the analyst (using a three-phase approach of *motivating, structuring* and *conditioning* - see section 3.4.1) to be able to quantify his/her beliefs as subjective probabilities.

(ii) The elicitation phase during which the subjective beliefs of the experts are elicited using a questionnaire that elicited the 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles of the subjective prior probability distribution for each uncertain input variable to project duration. The effects of central bias on the elicited percentiles were overcome in the questioning by eliciting the tails of the distribution first. This also ensured the display of sufficient spread in the distribution.

(iii) A feedback and consensus judgement phase during which the analyst, following the nominal group technique (see section 3.4.1), provides feedback to the experts on their estimates in the form of discussions between analyst and expert and expert and expert so that experts can revise their estimates and reach a consensus judgement for the group.

(iv) An analysis phase in which the subjective estimates are converted into moments (expected value and standard deviation) and shape characteristics (skewness and kurtosis) of the input variable.

(v) A verification phase in which the subjective prior probability distribution of the expert is verified to see if the expert would totally agree that the distribution reflects his/her beliefs. The first verification is ensured through a cross-checking mechanism in the questionnaire for consistency of the percentiles. The second verification is done by providing the expert with the moments and shape characteristics of the distribution implied by his/her estimates.

While the study successfully applies the elicitation technique to quantifying expert beliefs about economic risks, the analysis of the estimates assumes an approximation of the estimates to the Pearson family of distributions (Amos and Daniel, 1971). The present author contends that different risks may have different patterns of occurrences and impact and hence varying probability distributions. The "forcing" of expert estimates into particular fixed distributions therefore introduces elicitor biases into the elicitation and analytical phases. All estimates from experts (individual and consensus) should be acceptable as long as they are accurate, calibrated and coherent (Lindley *et. al.*, 1979).

(f) Eliciting expert opinions to determine the hydraulic conductivity of rocks

O'Hagan (1998) applies a group elicitation procedure to elicit consensus expert beliefs about the hydraulic conductivity of a specific rock stratum over a defined geographic area earmarked for the construction of a deep underground repository for nuclear waste. The experts, who were brought together in a group for the elicitation, were selected in a manner that would provide a spectrum of views and also cover a range of specialisms. The elicitation procedure is summarised below:

(i) The experts were asked to jointly specify the upper (U) and lower (L) limits of the distribution of the average hydraulic conductivity of the site. The estimates were provided using a logarithmic scale since the experts were used to thinking about conductivity on a logarithmic scale.

(ii) The experts then jointly specified and agreed on the mode (M) or most likely value of the average hydraulic conductivity of the site.

(iii) Probabilities for the quantity lying in the following intervals were elicited in a jumbled manner to avoid problems with anchoring (Tversky, 1974):

- (L, M)
- $(L, (L+M)/2)$
- $(M+U)/2, U)$
- $(L, (L+3M)/4)$
- $(3M+U)/4, U)$

(iv) Analysis of the results into the implied set of six probabilities which were then displayed as histograms.
(v) Feedback to experts using the histogram to provide them with the opportunity to revise the group estimates if necessary.
(vi) Verification phase with the experts that the probabilities accurately reflected their beliefs
(vii) Fitting of a beta distribution constrained to have a mode *M*, to the histogram
(viii) Investigating the possibility of obtaining a better fit for the probabilities that more accurately represented the experts' beliefs by adjusting the upper and lower limits (*U* and *L*) specified by the experts. This adjustment was considered in view of the difficulty that experts were found to have in judging high-coverage probability intervals accurately.

The approach used by O'Hagan (1998) is similar to that of Ranasinghe and Russell (1993) and shares similar analytical biases in fitting the results to a beta distribution.

The above studies, in spite of their limitations, clearly demonstrate the potential for applying subjective estimates and elicitation in contractual risks. Subjective predictions that were successfully made on the elements of the weather were based on the forecasters' knowledge and experience of weather patterns in much the same way that the construction experts' knowledge and experience of patterns in the conditions for the occurrence and impact on contractual risks such as adverse ground conditions or payment delays could guide his predictions about such risks. O'Hagan's (1998) study further demonstrate that the elicitation or technically complex opinions could be done if the experts are allowed to express their opinions in the "language" they normally speak in. In the case of eliciting expert beliefs about the hydraulic conductivity of rocks, the best method of expression was the logarithmic scale since the experts were used to thinking about conductivity on a logarithmic scale. All the studies also point to the need for a computerised approach to the elicitation process in view of the volume of data and analysis that needs to be handled.

1.3 The Research

The available literature suggest that although the majority of the contractual risks inherent in construction projects are fairly well known, the perceptions of the project parties of the project risks largely determine the attitude and approach to the management of the risks, and greatly influence the project price and performance. It is the author's belief, in line with research on risk perception, that where a contract requires a contractor to undertake a project in a different socio-cultural and technological context (international project), the different project context will tend to increase the degree of divergence of the perceptions held by the international contractor(s) and their local counterparts, and hence lead to an over- or under-statement of the risk and the risk-reward values. Since estimates of contractual risks are heavily influenced by such perceptions, there is the need to capture and analyse these perceptions in a manner that will foster their effective input into the total risk analysis and management effort.

The key stumbling blocks to the application of a rigorous and systematic approach to contractual risk analysis have been the extra cost of pursuing a rigorous and systematic process, and the unavailability of relative frequency data on the separate risks. Yet evidence from other industries indicates that elicitation techniques and subjective probability analysis can indeed be successfully applied to contractual risks, and thereby achieve a higher and globally comparable standard of rigour. The author believes that a careful study and understanding of the nature of the perceptions about contractual risks will lead to the development of a risk elicitation model and a more rigorous, systematic and effective analysis and management of contractual risks in construction using subjective probabilities.

1.3.1 The Focus of the Research

The focus of the research is to investigate the use of elicitation and probability analysis techniques in quantifying expert opinions as subjective probabilities for use as input variables in the analysis and management of contractual risks in construction. The study also aims to make the results applicable within international contracts by attempting a cross-cultural study that analyses risk analysis approaches in both United Kingdom and Ghana, and investigating the use of elicitation within such cross-cultural settings. By developing an elicitation model through this study, it is hoped that British contractors, for example, can cost-effectively generate contractual risk variables that can then be used as an additional component in their risk analysis and estimation of international project risks in countries with which they are unfamiliar. By developing a cost effective way of generating such input data for analysing contractual risks, the study hopes to extend the benefits of rigorous and systematic risk analysis to construction risk management and thereby enhance construction project understanding and performance. It is also intended that the research would lead to the development of software for eliciting, analysing and managing contractual risks in construction.

1.3.2 Aims and Objectives of the Research

The essence of the study is to provide better understanding of the nature of contractual risks and techniques that can be applied to their rigorous and effective analysis. This is achieved through an investigation of current risk management practices and the nature and impact of risk perception of the estimation process. Specific objectives towards achieving these are:

(a) To conduct a review and survey to establish the types of risk management techniques currently in use in the construction industry, and the extent of their usage;

(b) To investigate risk perception in the construction industry and its impact on project performance (price).

(c) To develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception risk perception on individual estimates of risk, and provides these opinions as an input variable to the systematic and effective analysis of contractual risks.

1.3.3 Scope of the Research

Although it is believed that the results of the study can be widely applied in infrastructural projects development generally, the study focuses on construction projects, and on Ghana and the United Kingdom. Primary data obtained from the interviews and surveys in these two countries provide the main empirical basis for the research. The choice of Ghana and the United Kingdom were predicated on the following reasons:

(a) The relevance and applicability of results: Ghana and the UK present two different socio-economic cultures and thus are naturally good subjects for the study. Furthermore, Ghana has been used as a model by the World Bank for the economic development of other developing countries. With the opening up of the Ghanaian economy (and many other developing economies for that matter) a comparison between the two countries makes the results of the study immediately relevant to contractors from a developed economy (UK) seeking to enter a developing economy (Ghana).

(b) The similarities between the legal and contractual systems of the two countries. As a former British colony, much of Ghana's legal and contractual systems are based on the British systems. The similarities between the two systems reduce complexity of research variables and therefore increase accuracy of the results.

(c) The author's familiarity with both countries. Given the time and budgetary constraints on the research, such prior knowledge is considered an asset that should be utilised to keep the project within both cost and time constraints.

1.4 Organisation of the thesis

An adventure in an enhanced understanding of risk and risk management cannot begin without a clarification of the concept or risk and its various ramifications, and a review of the current body of written work on risk. Chapter 2 therefore introduces the key concepts that are fundamental to the understanding of risk and the research. It reviews the current literature on construction risks and techniques for managing risks in construction projects, including an examination of the techniques reported in the literature as being the major analytical method currently used for construction risk analysis.

Chapter 3 provides a comprehensive review of the literature on the analytical techniques related to the research. In particular, it presents a critical review of the literature on subjective probability and techniques for eliciting subject expert opinions as input variables for the analysis of risks and uncertainties. It also discusses how these techniques apply to the analysis of contractual risks in construction.

Chapter 4 examines the literature relating to the methodical issues of the research and establishes the basis for the research design and the design of the survey instruments developed for this research. Data characteristics, sampling method and background information on the survey undertaken are presented. An explanation of the techniques employed in analysing the data is also provided. The chapter concludes with some comments on the research methodology to provide the limits and context of findings of the study.

Empirical results from the survey questionnaires and interviews conducted among construction experts in the United Kingdom and Ghana are presented together with their analyses in Chapter 5. This chapter has three main parts. The first part discusses the practice of risk analysis in construction and presents the key risk analytical techniques currently used in the industry. The second part discusses the results of the survey on risk perception and evaluates how the adverse effects of individual perception expressed in subjective estimates of risk can be overcome by the aggregation of expert opinions. The final part presents the analyses and development of expert opinions elicited by the survey into subjective probability estimates and the application of Bayesian analytical approach to the subjective estimates generated by the research. This part therefore provides the final part of the jigsaw needed to form a basis for the development of a procedural model for managing contractual risks in construction.

Chapter 6 presents the conclusions and recommendations of the study by first bringing together all the key aspects of the study into the development of the model for the systematic analysis of contractual risks in construction. The limitations and weaknesses of the study are also presented to provide a further basis for the recommendations of the study presented to conclude this chapter.

The appendices following the body of the thesis documents the survey instruments used in the pilot and main studies.

1.5 Summary

The purpose of this chapter was three-fold. First, it was to provide a background to the current research and discuss the factors that necessitated the research. Secondly, it was state the aims and objectives of the research define the context within which the research was done. Lastly, it was to guide the reader through the rest of the thesis in as logical a manner as possible. The first part of the chapter thus explained the *fact* of risk in life and how risk permeate the both the business decision-making and construction project environments. It briefly discussed the use of formal risk management processes in the management of various risks inherent in construction projects, and highlighted the lack of application of systematic and rigorous methods involving the elicitations of expert opinions and subjective probabilities to the analyses contractual risks. This is despite the fact that applications of this nature in other industries point to the enormous potential that such methods present to the construction industry, especially to the international construction environment where the perceptions of the project parties play an enhanced role in project performance.

The second part of the chapter stated some of the reasons given by the industry for the lack of use of such rigorous methods and explained how these hindrances could be overcome through the study. It proceeded to state the aims and objectives of the study and to define the industrial, cultural and economic foci of the research and the rationale for such foci. The last section of the chapter discussed the organisation of the thesis and how the interrelationship between a chapter and the next.

Having provided this background to the current research, the next chapter provides a discussion of the key concepts that are fundamental to the understanding of risk and the research. It reviews the concept of risk in more detail and discusses current literature on construction risks and techniques for managing risks in construction projects.

CHAPTER 2

THE MANAGEMENT OF CONSTRUCTION PROJECT RISKS

2.0 Introduction

Risk pervades all construction activities that require formal project management. The effective management of the risks inherent in a construction project is critical not only to the success of the project and the profitability of the contracting parties, but also to the long-term performance of the construction industry as a whole. In seeking to manage the economic risks in construction projects, various techniques and processes are used. Most of these techniques and processes are fairly well understood and documented. This research focuses on contractual risks, which, by their nature, are subject to more personal biases and individual perceptions than economic risks to which most of the documented formal techniques and processes of construction risk management seem to apply. This chapter reviews the current literature on construction risks and techniques for managing risks in construction projects. It also presents further critical examination of the theories and evidence presented by existing work on the techniques and processes for managing contractual risks in construction. The first part of the chapter provides the theoretical and conceptual framework for understanding risk in general, and construction risks in particular. The second part discusses the major systems and processes for managing risks in construction. Finally, the third section looks at risk analysis techniques in closer detail as they relate to contractual risks, and presents critiques from which a basis for the focus of the present research is derived.

2.1 The Concept of Risk

Chapter 1 dealt with the subject of risk as though it had a universally accepted definition and meaning. While the use of the word in everyday life would seem to suggest so, this is by no means the case. In the "professional" world of risk, there are significant differences in opinion when it comes to defining the nature and meaning of risk in both everyday and scientific terms. Economists, behavioural scientists, risk theorists, statisticians and actuaries each have their own concept of risk and often, the result of getting members of different professions to agree to a single definition of risk is confusion. For example in 1983, the Royal Society of Britain produced a report called

"Risk Assessment" which became a major work of reference on the subject of risk because of its authoritative, confident and purposeful presentation. In 1992, only nine years afterwards, the society invited a group of social scientists from psychology, sociology, anthropology, economics and geography in addition to the physical scientists to discuss the same issue of risk. The social scientists, with the exception of the economists, could not agree with the physical scientists about the nature and meaning of risk! In order to set this work in its proper context, it is necessary to an appropriate definition of risk to act as a reference point for the discussions in this report.

In his review of Kedar (1970), Wharton (1992) traces "*risk*" to its Arabic (*risq*) and Latin (*risicum*) origins. He explains how both the original use and the Greek derivative of the word tended to relate to chance outcomes in general terms. In this original use, "*risk*" had neither negative nor positive implications. Cooper and Chapman (1987) also present this view of risk. They define risk as the "*exposure to the possibility of economic or financial loss or gain, physical damage or injury, or delay, as a consequence of the uncertainty associated with pursuing a particular course of action*". According to Raftery (1994), "*risk and uncertainty characterise situations where the actual outcome for a particular event or activity is likely to deviate from the estimated or forecast value*". Chapman and Ward (1997) also define project risk as "*the implication of the existence of significant uncertainty about the level of project performance achievable*". The Institution of Civil Engineers and the Faculty and Institute of Actuaries jointly supported a working party for developing a process for evaluating and controlling risks in major projects. This working party also adopted this wider view of risk and defined risk as "*a threat (or opportunity) which could affect adversely (or favourably) the achievement of the objectives of an investment.*" (ICE, *et al.*, 1998). In his application of quantitative risk management to refinery construction, Dey (2002) also adopts the definition of risk presented by Cooper and Chapman (1987).

Wharton (1992) suggests however, that although the word *risk* in its original meanings has connotations of fortuitous and favourable or unfavourable outcome, over time and in common usage the meaning of the word has changed. From an original usage of simply describing any unintended or unexpected outcome of a decision or course of action, the use of *risk* now relates to undesirable outcomes and the chance of their occurrence. In line with this current meaning, the Royal Society (1983) defined risk as "*the probability that a particular adverse event occurs during a stated period of time or the result from a* *particular challenge. As a probability in the sense of statistical theory, risk obeys all the formal laws of combining probabilities."* An adverse event in this context was defined as *an occurrence that produces harm.* The view that relates risk to undesirable outcomes and the chance or uncertainty of their occurrence prevails among both ordinary people and professionals. For example, The Oxford Advanced Learner's Dictionary (Hornby, 1989) defines risk as *"(the instance of) the possibility of meeting harm, loss, etc".* The Webster's Third New International Dictionary (1986) defines risk variously as "*the possibility of loss, injury, disadvantage or destruction; ... someone or something that suggests a hazard or adverse chance: - a dangerous element or factor; ... the chance of loss or the perils to the subject matter of insurance covered by a contract; the degree of probability of such loss; ... the product of the amount that may be lost and the probability of losing it*"

These definitions agree with both that provided by the British Standard Institution (1979) which defines risk as *the combined effect of the occurrence of an undesirable event and the magnitude of the event*, and that provided by the Construction Industry Research and Information Association (Godfrey, 1996) as *the chance of an adverse effect.* Thus, risk involves variability in both the frequency and severity of an undesirable outcome.

The term *opportunity* is used by some authors to describe the possibility (or risk) of a favourable outcome (Construction Industry Institute, 1989; Dawson, 1997). The author contends that in the context of infrastructure project development, it is the opportunity (potential benefits or rewards) offered by a project or investment that motivates both construction clients and contractors to engage in the project. For all practical purposes therefore, the intentions of parties in dealing with project risks is to apply the most appropriate systems to eliminate or reduce the occurrence and impact of the *things that can go wrong* on the project in order to ensure the achievement of the maximum or optimum benefits (opportunities). Thus, although the object of risk management would be the maximisation of opportunity, the risk management effort itself focuses on identifying and eliminating or controlling undesirable events and their impacts on the project. The practical understanding and application of the term '*risk*' in construction therefore carries with it the negative connotations.

This view of risk as carrying negative connotations is shared by many in the actuary and insurance professions for whom risk is the central object of study. For example, the

Society of Actuaries holds the definition of economic risk as *the possibility of losing economic security* and uses the standard deviation of the possible outcomes of an event as a measure of risk (Anderson & Brown, 2000). Using the uncertainty basis for risk definition used by traditional insurance authors, Redja (1982) defines risk as the *uncertainty concerning the occurrence of a loss.* Vaughan (1997) defines risk as *a condition in the real world in which there is an exposure to adversity or a possibility of an adverse deviation from a desired outcome that is expected or hoped for.*

In an attempt to resolve the problem of lack of a unified definition of risk, some authors (e.g. Flanagan and Norman, 1993) use the differences among the various combinations of the occurrence and consequences of risk to provide a classification of risk. These classifications are discussed later in this chapter. For the purposes of this study however, the negative meaning of risk is taken. This view of risk is considered most appropriate because in dealing with contractual risks, there are generally (and for all practical purposes) no positive outcomes associated with the risks, as far as project objectives are concerned. For example, encountering unforeseen or adverse ground conditions can only result in negative impacts on project resources such as time and funding and anticipated cash flow. Risk is thus defined herein as:

"The probability that a particular undesirable event with potentially adverse consequences occurs during a stated period of time as a result of the uncertainty associated with pursuing a particular course of action. In mathematical terms, it is the product of the probability of occurrence (likelihood) of the event and the magnitude of the effect (impact) should the event occur."

2.1.1 The Essential Attributes of Risk

While the above definition offers a succinct and practical definition of risk, it is important to go beyond this definition and explore the composition of risk. This is necessary in order to gain a better understanding and appreciation of risk management and this study. This understanding is also important because in risk management, we are interested in more than just identifying things that can go wrong. We are also interested in addressing the issues of what can make things go wrong, what are the chances that things would go wrong and what would be the effect on the desired objectives if things went wrong.

Implied in the definition of risk adopted above for the purposes of this study therefore, are the following attributes of a risk (Al-Bahar & Crandall, 1990; Flanagan & Norman, 1993; ICE *et. al.*, 1998):

(a) *Risk sources or threats:* the broad range of forces or things that can produce adverse results, e.g. defective equipment, or unforeseen weather conditions on site.

(b) *Risk targets or subjects:* the assets, people or earnings that can be affected by a risk threat. In the context of a construction project, these are those elements of a project such as time, money, etc., on which the operations of a project depend for continuity.

(c) *Risk event:* a possible occurrence that can adversely affect one or more risk targets or the achievement of the desired objectives. For example, late payment to contractor by the client or injury to workman on site

(d) *Risk likelihood:* the chance or probability of a risk event occurring within a defined time period

(e) *Risk impact or effects:* the manner in which, or the extent to which a risk source manifests itself on its target(s) as a result of a risk event. The death of a worker and a 7-day delay in project completion caused by the collapse of scaffolding (the risk event) are examples of risk impacts. In economic terms, risk impact is the financial value of the effect of the risk event on one or more risk targets.

(f) *Expected value of a risk:* the average impact of a risk event on its targets over time or a large number of similar projects. In mathematical terms, this is calculated as the product of the *risk likelihood* and the *risk impact.*

While significant disagreements exist in the definition of risk, there hardly exists any such confusion over the essential elements and categories of risk. The scope of the element of risk in question may however, differ from one author to the other depending on the view of risk held by an author. For example while the present author's definition of risk event carries a negative connotation, the definition offered by ICE *et al.* (1998) carries the wider view of both positive and negative outcomes for the risk event.

2.1.2 Classification of Risk

Project/investment decisions and actions are driven by the prospects of a favourable return or profit. Project plans are put in place and executed with this in mind. When things go wrong on a project, a loss is suffered in one or more areas of the objectives of the project. This loss represents the risk(s) of the project. The loss or risk arises from a variety of causes and impact on the investment in different ways. To aid a better understanding of the nature and types of risk that a project is subject to, the differences in the causes and effects of risks are often used as a basis for classifying risks. A brief review of the classification of risks is presented here in order to provide an understanding of how contractual risks relate to the other types of risks associated with construction projects and that are often found in the risk literature. A detailed review of the nature and types of construction risks are presented in section 2.1.3. A project here is defined in simple terms as any organised business activity in which an investment is made, whether it involves the creation of a physical asset or not (ICE *et. al.*, 1998). More specifically, it is *an endeavour in which human, material and financial resources are organised in a novel way, to undertake a unique scope of work of given specification, within constraints of cost and time, so as to achieve unitary, beneficial change, through the delivery of quantified and qualitative objectives* (Turner, 1992 as quoted in Chapman and Ward, 1997).

Against this background, risk is often classified into the following categories:

(a) *Financial and Non-financial risks:* Some degree or risk is involved in every pursuit of man and many of these risks carry only incidental, if any financial loses at all. Financial risks arise from projects that comprise a relationship between an individual or an organisation and an asset or expectation of income that may be damaged or lost (Vaughan, 1997). In addition to possessing the essential elements of risk described in section 2.1.1 above, a financial risk also has the element of a person or an entity who will be affected by the occurrence of an adverse effect because of his/her ownership of the asset or income whose destruction or dispossession will cause financial loss. Thus, an individual or entity who owns nothing of value or whose assets or expected incomes are not subject to any possible adverse effects faces no financial risk. Construction projects that are of concern to this study involve huge investments by both individuals and organisations from which both assets and incomes are expected. Thus, all construction projects are associated with financial risks. Specifically, because the occurrence of a contractual risk ultimately involves a project party in financial loss, they also represent financial risks.

(b) *Pure and Speculative risks:* Redja (1982), Flanagan & Norman (1993) and Vaughan (1997) define *pure risk* as a situation in which there is only the possibility of loss or no loss but no potential gain. Such risks normally arise out of the possibility of accidents or failures in one or more aspects of a project. Pure risks include personal risks, property risks, liability risks and risk arising from the failure of others. Personal risks include the risk of premature death (and the concomitant potential for great financial and economic insecurity), the risk of old age (and the potential for insufficient retirement income), the risk of poor health (resulting often in major medical expenses and loss of earned income) and the risk of unemployment, which is a major threat to financial security. While personal risks are a subject that makes interesting study, it is not the subject matter of this research. Property risks include direct losses (*loses which result directly from an insured peril;* for example damage to, or loss of the property), consequential losses (*losses that are the consequence of some other loss*, for example the loss of revenue as a result of physical damage to a shop) and extra expenses (*additional expenses incurred as a result of the loss or damage*, for example the cost of temporarily relocating or re-organising a shop due to physical damage, in order to continue trading and retain customers). Liability risks are the losses of present assets or future income that result from the intentional or unintentional (negligence or carelessness) injury of other persons or damage to their property. Pure risk also exists when the possibility of failure of another person obligated to perform a service would result in the financial loss of the person to whom he/she is obligated. This risk always exists in all construction projects that involve subcontractors. Contractual risks are pure risks in that there are generally no expectations of gain associated with their occurrence.

Speculative risks on the other hand describe those situations where there are clear possibilities for either a loss or a gain, such as gambling. The distinction between these two types of risks is important to understanding risk management, especially risk allocation for several reasons. Firstly, only pure risks are insurable (although not all *pure* risks are insurable). Secondly, most pure risks are easily predictable due to the applicability of the law of large numbers to those risks. With the exception of gambling, it is generally more difficult to apply the law of large numbers to speculative risks and thereby predict future outcomes. Thirdly, whereas no benefit arises out of the occurrence of a pure risk, benefits can arise out a speculative risk whose direct outcome is a loss. For example, whereas the flooding of a construction site can only result in a loss, the development of a new, more efficient but lower-cost technology can force a competitor company out of business and at the same time result in overall industrial and societal benefits due to the higher efficiency and lower cost to consumers.

(c) *Dynamic and Static risks:* Dynamic risks are *speculative risks* that arise out of changes in the external environment such as the economy, industry, competitors and consumers, or the internal environment such as management decision within the firm. For example, changes in the infrastructural policy in certain developing economies (e.g. Ghana) can create a 'Stop-Go' process in the construction industry and significantly affect the project performances of certain government-funded projects. Since they are concerned with adjustment to misallocation of resources or the maximisation of opportunities, they affect more individuals and may have a wider and beneficial impact on society as a whole (Reidja, 1982; Vaughan, 1997). Static risks on the other hand are *pure risks* connected with losses that arise out of the irregular action of nature or the mistakes or misdeeds of human beings and would exist even in an unchanging economy. Because of their predictability, they are more suited to treatment by insurance than dynamic risks. Dynamic risks can often affect the state of a construction contract and therefore involve a project party in a loss. For example, changes in the infrastructural policy of the government of certain developing economies (e.g. Ghana) due to budgetary changes often causes protraction in project duration and significant financial losses to the contractor.

(d) *Fundamental and Particular risks:* The distinction between these two is based on the differences in the origin and impact of the losses. Fundamental risks are risks that affect the entire economy or groups or large numbers of persons within the economy (e.g. high inflation). They arise mainly from economic, social and political phenomena. Government action is often necessary to insure against fundamental risk. National unemployment benefit programmes are an example of government insurance for the unemployed in the economy. Also, following the September 11, 2001 terrorist attack the USA, the US government in November 2002 instituted a policy that in essence provided insurance for companies against such and similar risks. Particular risks on the other hand are losses that arise from individual events and affect only the individual concerned. They may be static or dynamic and are considered the responsibility of the individual, e.g. the loss or theft of a person's car. Contractual risks may be either *fundamental* or *static*.

(e) *Diversifiable and Non-diversifiable risk:* A risk is considered diversifiable if its impact can be reduced through pooling or risk sharing. This is often possible if the risk is does not affect organisations or individuals in the same way and at the same time (Williams, Smith & Young, 1998). A risk is non-diversifiable if risk-sharing or pooling systems would be ineffective in reducing its impact. An economic recession is an example of a non-diversifiable risk whereas the risk involving deviations of individual security returns from the group average in a diversified securities portfolio represents a diversifiable risk.

(f) *Objective/Real and Subjective/Perceived Risk:* Risks are often also categorised according to the two broad approaches by which risks are measured. Risks that are purportedly measured by the actual observation or calculation of their occurrence and/or impact on a process or project are often described as "Objective" or "real" risks. Measurements for "Objective" or "real" risks are quantitative in nature and often structured in probabilities. They involve experimental evidence, long-term experience (recorded data) or sophisticated analytical calculations that describe actual or potential risks. The second category of risk measurements are "subjective" in nature and describe what people "perceive" to be the risks of a particular activity to be (Kasper, 1980). Huczynski & Buchanan (1991) define perception as the "the active psychological process in which stimuli are selected and organised into meaningful patterns". Risks for which subjective measurements are applied are referred to as "subjective" or "perceived" risks. Although some contractual risks (such as death or injury on a construction site) can lend themselves to quantitative analysis, the majority of contractual risks would be described as subjective.

2.1.3 The Nature and Types of Risks in Construction

Although the development of an appropriate strategy for managing project risks will differ from client to client, contractor to contractor and from project to project, a sound understanding of the nature and types of risks involved in any particular project is equally important to all the parties involved in the project. This depth of understanding not only expands awareness about the risks involved in the project, it also directly impacts on the risk management strategy adopted by the project parties since the developing the most appropriate strategy for managing the project risks varies according to the nature of the risks (Al-Bahar & Crandall, 1990) and the type of risk (Perry & Hayes, 1985).

Various analysts have presented various analyses and classifications of construction project risks. Some of these analyses, (Erikson, 1979; Ashley, 1981, Raftery, 1994) although helpful in helping the project parties identify some of the risks involved in the project, make no attempt to classify the risks by their nature and potential impact, nor do they recognise the relationships between different risks (Al-Bahar & Crandall, 1990). They thus fail to point the parties in the direction of developing appropriate strategies for managing risks. The analysis from Perry & Hayes (1985) provide a comprehensive classification of construction project risks, but fails to address the impact and relationships of these risks as their analysis is limited to the appraisal stage of the project development. On the other hand, analysts such as Al-Bahar & Crandall (1990) attempt to classify the risks by their nature and potential impact and recognise the relationships between different risks, but fail to provide a comprehensive analysis of construction project risks. Strassman & Wells (1988) discusses several risk factors from the differing perspectives of the client and contractor, and Kangari (1995) presents 23 risk descriptions categorised as owner risks, contractor risks or shared risks, based on a survey of the top 100 US construction contractors. While these studies and other analyses of risks are useful in highlighting potential risks in a construction project, they do not offer the level of comprehensive analysis that will guide and enable a contractor or client to develop a unified and effective strategy for managing project risks.

Perhaps the best analysis of construction risks to-date is the one offered by Hastak & Shaked (2000). In analysing project risks in the context of international construction, it is important to identify how that project is likely to be affected by the geo-political and market environment in which it is set. Hastak & Shaked (2000) therefore argue that for a better understanding of international project risks, the risks should also be analysed at three different levels:

(i) *Macro (or Country) Level Risks*: These are the risks to the contractor/investor while expanding operations in a given country. They include operational risks such as the political continuity of the host government, political risks such as hostilities with neighbouring countries and legal/financial risks such as the laws and practice regarding repatriation of capital.

(ii) *Market Level Risks*: These are the risks associated with the construction market within the selected country. They include risks faced by the local construction companies such as the impact of the macro level risks on the country's construction market, and additional risks that the international construction company will need to deal with. These additional risks include the types of contracts/bidding procedures and business cultural differences and what impact they have on the interaction between foreign management and local contractors.

(iii) *Project Level Risks*: These are risks associated with the project as set in its specific international context. It therefore includes the impact of both the macro and market level risks on the project.

However, the analysis presented by Hastak & Shaked (2000) is limited to use of the Analytical Hierarchy Process (AHP) developed by Saaty (1980) to determine the relative importance of the risks and the interrelationships among the risks. It does not analyse the risks in terms of ownership of the risks or which project party would have the most direct influence on the risk.

This section draws from the works of Hastak & Shaked (2000) and others to provide a comprehensive analysis of construction project that enables a fuller understanding of the nature of the risks and enables a contractor or client to develop a unified and effective strategy for managing project risks. This is achieved by providing a detailed classification of risks at each of the three-levels proposed by Hastak & Shaked (2000). Classification at each level covers the risk source, risk type, risk category, risk targets and the potential impact of the risk. Tables 2.1, 2.2 and 2.3 provide details for each level of classification. Thus, the risk of inflation during construction is a fundamental and speculative risk that affects the cost of the project, the profitability of the contract and the sustainability of the project. This risk is speculative as it presents possibilities for either a loss or a gain. It is also fundamental because it arises from economic, social and political phenomena and affects the entire economy within which the project is set. It is thus a macro level operational risk that is outside the control of any of the project parties even though it is a financial/economic risk that could involve the parties in either more expense or diminished value of revenue or profit.

Risks vary from project to project and from country to country. It is therefore not claimed here that the risks presented in the tables below are exhaustive. They are however very comprehensive in their indication of the nature and types of risks in construction projects.

2.2 Systems and processes for managing construction project risks

It is apparent from the tables above that the environment in which construction project decision-making takes place is characterised by risky and uncertain circumstances brought about by a dynamic mix of controllable and uncontrollable factors. The process of developing a project from basic ideas and mental concepts through feasibility studies, architectural and engineering design, procurement, construction and commissioning to maintenance is not only complex, but involves myriad people of diverse backgrounds, skills and aspirations brought together by complex and tiered relationships to achieve a common goal: the project. When one considers the compounding effect on such complexity of other macro and market factors that are often totally outside the direct control of the project parties, and the complicated contracts which govern the construction process itself, then the need for the systematic management of project risks towards achieving desired project goals become self-evident. International construction projects, which are generally large-scale, present another level of challenge. It is thus not surprising that Dey (2002) argues that conventional project management techniques are not always adequate in ensuring that the project objectives of schedule, cost and quality are met on such large-scale project.

Table 2.1: Nature and Types of Macro Level Risks in International Construction Projects

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Operational	• Host Government - Political continuity - Attitude towards foreign investors and profits - Nationalisation/expropriation - Enforceability of contracts - Government incentives	• Fundamental & Pure	• Time	• Delays to project completion
	• Economic & Financial - Monetary inflation - Economic growth	• Fundamental & Speculative	• Cost	• Higher/lower project costs
	• Administration - Bureaucratic delays - Communication/transportation - Non-construction professional services	• Fundamental & Pure	• Time	• Delays to project completion
Political	• External factors - Hostilities with neighbouring country or region - Dependence on/importance of Major power	Fundamental & Pure	• Time & Cost • Time & Cost	• Delays to project completion and extra cost of delays • Delays to project completion and extra and extra cost of delays
	• Internal factors - Fragmented political structure - Fractionalisation by language, ethnic or regional groups - Restraints to retaining power - Mentality such as nationalism, corruption and dishonesty. - Social demographics (population/wealth)			
	• Stability - Societal conflicts (e.g. strikes) - Non-constitutional changes		• Time & Cost	• Delays to project completion and extra and extra cost of delays

Table 2.1 *(Continued)*

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Financial	• Legal framework - Actual versus practices for repatriation of capital • Foreign Exchange generation - Current account balance - Capital flow • International Reserves - Foreign exchange reserves - Gold and other reserves • Foreign debt assessment - Debt as GDP (in UK £s) - Capacity service debt • Budget Performance - Extent of deficit/surplus - Sources for revenue and spending	Fundamental & Dynamic	Time	Project/payment delays resulting from capital flow restrictions and foreign exchange restrictions and/or shortage

Table 2.2: Nature and Types of Market Level Risks in International Construction Projects

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Technology	• Investor's technological advantage • Technology protection system* • Market suitability for advanced technology • Availability of basic construction technologies and equipment	Fundamental & Speculative	Time, cost and quality	• Cost/time savings or increases due to technology. • Impact of technology on quality of work
Contracts & Legal requirements	• Type of partnership • Type of contracts • Enforceability of construction contract* • Procedure for bidding and design approvals*	Fundamental & Pure	Time and cost	Delays/costs due to disputes and/or procedures
Resources	• Availability and quality of local contractors • Availability of construction materials* • Availability of skilled and unskilled workers • Labour cost/productivity • Availability of equipment and parts	Fundamental & Speculative	Time, cost and quality	• Quality of workmanship from local contractors • Quality, cost and productivity of local labour and equipment
Financing	• Medium and long term financing for construction projects* • Tax and non-tax incentives in construction industry* • Special construction industry index*	Fundamental & Speculative	Time and cost	• Project delays due to lack of long term financing • High project costs due to lack of incentives
Business cultural differences	• Interaction of foreign management with local contractors • Architectural, Engineering and Construction firms relationship with client or owner • Competitive/negotiated bidding	Fundamental & Speculative	Time and cost	• Difficulties in resolving disputes • Cost savings arsing from competitive bidding
Market Potential	• Current and future Market volume in core competency • Bidding volume index*	Fundamental & Speculative	Cost	Impact of low market potential on how the cost of entry into the new country is applied to the project

Note: * implies impact from market level risk(s).

Table 2.3: Nature and Types of Project Level Risks in International Construction Projects

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Physical	• Force Majeure (Acts of God) - earthquake, flood, fire, etc • Pestilence • Disease	Fundamental and Static	Time, cost and human resources	Project delays, loss of lives and associated costs
Political	• Changes In law • War, revolution, civil disorder • Constraints on the availability of labour • Customs and export restrictions and procedures • Requirement to use local labour or management • Requirement to joint venture with local organisations • Inconsistency of regulations within country or organisation • Requirement for permits and the procedures for their approval; for building codes and planning permits • Embargo	Fundamental and Pure	Time, cost, quality and human resources	Project delays, poor quality due to poor quality of labour, loss of lives and associated costs
Environmental	• Ecological damage • Pollution • Waste treatment • Public enquiry • Regulations and possible changes • Recording and preserving historical finds • Minority interests	Fundamental and Pure	Time	Project delays

Table 2.3 *(Continued)*

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Design	• Incomplete design scope • Availability of information • Innovative application • New technology • Level of detail required and accuracy • Appropriateness of specification • Likelihood of change • Interaction of design with method of construction • Non standardisation of details • Non standardisation of suppliers • Quality control exercised • inspection and approvals • Temporary design - quality, responsibility and supervision	Particular and Pure	Time, cost and quality	Protracted schedule, higher costs or lower quality due to design issues
Legal and contractual	• Direct liability • Liability to others • Local law and codes • Legal differences between countries of client, contractors, consultants, suppliers • Conditions of contract; e.g. - liquidated damages, - maintenance - change to 'expected risks' • Possibility of disputes	Particular and Speculative	Time and cost	Protracted schedule and cost overruns due to legal and contractual issues

Table 2.3 *(Continued)*

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Construction	• Weather	• Fundamental & Pure	• Time	Project delays, increased costs, lose of health/life and poor quality arising from various risk types
	• Delay in Possession of site • Access • Productivity of equipment - possible failure • Availability of equipment, spares, fuel • Inappropriate equipment • Quality, availability and productivity of labour - manual and management • Capability of professional staff - competence, unreasonableness, partiality	• Particular & Pure	• Time and Quality	
	• Industrial relations • Labour - sickness, absenteeism • Suitability, availability and supply of materials • Supply of manufactured items		• Time and Costs	
	• Quality, availability and productivity of subcontractors • New technology or methods - application and feasibility		• Quality	
	• Delay in information from designers • Liaison with public services		• Time	
	• Safety - accidents	• Particular & Static	• Time, Cost and Human resources	
	• Extent of change		• Time	
	• Failure to construct to programme and specification		• Time and Quality	
	• Poor workmanship • Poor quality of materials		• Quality	

Table 2.3 *(Continued)*

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Construction *(continued)*	• Ground conditions - inadequate site investigation, inadequate information in documents, unforeseen problems • Mistakes • Relationship of professional staff to each other - consultants, architects, quantity surveyors, contractors • Co-ordination of all construction contractors • Irregularity of work load • Wastage • Theft • Errors or omissions in bills of quantities • Insufficient time to prepare bid tenders • Communication • Poor design and shop drawings • Damage during transportation or storage • Damage during construction due to negligence of any party, vandalism, accident	Particular & Static	Time, Cost and Quality	Project delays, increased costs and poor quality arising from various risk types

Table 2.3 *(Continued)*

Risk Source	Risk Type	Risk Category	Primary Risk Targets	Potential Risk Impact(s)
Financial	• Availability of funds of client • Cash flow of client - particularly effect of delay • Loss due to default of contractor, sub-contractor, supplier, client • Cash flow problems for contractors due to - slow payment by clients of certified work or claims - dispute • Adequate payment for variations • Failure of low bidder to enter construction contract • Credit worthiness of contractor • Inflation • Exchange rate fluctuation • Availability and fluctuation of foreign exchange • Difficulty of converting local currency to foreign exchange • Repatriation of funds • Local and national taxes • Cost of legal decision • Insufficient insurance • Business disruption • Bid validity period extension • Bid and construction bonds unfairly called	• Particular & Static • Particular & Dynamic • Particular & Pure	Time and Cost	Project delays and increased costs arising from various risk types

2.2.1 What is Risk Management?

As an informal art, risk management has been in existence since the dawn of time. Humans pull together into communities in order to share risks in life. In a modern context, we see the practice of risk management any time a cyclist puts on a helmet or a passenger puts on a seat belt. As a formal science under formal scholarly study, however, the practice has evolved only since the mid-1950s (Williams *et. al.*, 1998). Even though the concept of risk management has common understanding across practically all industries, the practice of risk management as a formal management function varies among different industries and different areas of application. So do definitions of risk management. For example, Williams & Smith (1998) defines risk management from an organisational perspective *as a general management function that seeks to assess and address the causes and effects of uncertainty and risks on an organisation.* Tummala *et al.*, (1994) and Burchett *et al.*, (1999) define risk management as *a logically consistent framework to develop a process of finding and understanding alternative risks, assessing their risks and uncertainties, identifying the resources needed and choosing appropriate courses of action in coping with these risk factors and in achieving the desired results.* From a general project management viewpoint, the Project Management Institute defines risk management in its Project Management Body of Knowledge Guide (PMBOK) as the "*processes concerned with identifying, analyzing, and responding to project risk*" (Project Management Institute, 2000). Uher & Toakley (1999) also define risk management as *a procedure to control the level of risk and to mitigate its effects.* Flanagan and Norman (1993) define risk management as *a discipline for living with the possibility that future events may cause adverse effects* while Chapman & Ward (1997) define project risk management as *the systematic identification, appraisal and management of project-related risks in order to improve project performance.*

This study looks at risk management from the perspective of construction projects within an international context. Thus, even though effort is made to apply concepts and practices from other industries to achieve the objectives of the research, the studies limits its reviews of the definitions and processes of formal risk management to the construction industry. Against this background, project risk management is defined as *the general project management function that involves the formal and systematic process of identifying, analysing and developing planned responses to the risks and* *uncertainties that could have an adverse impact a construction project, in order to eliminate or minimise the consequences of possible adverse future events and optimise the achievement of project objectives.* Implied in this definition is the understanding that project risk management has the following attributes:

(a) It is concerned with all types of risks that affect a project (i.e. it is a *general project management function* as opposed to a sub-function such as Design).
(b) It is discipline (i.e. it is *formal and systematic*) that requires advanced preparation (i.e. it generates *planned responses*)
(c) It encompasses both risk and uncertainty (e.g. poor workmanship or design changes) management rather than just loss management
(d) Its purpose to enable project parties to progress towards project objectives in the most exact, efficient and effective manner.

2.2.2 Risk Management Systems and processes

Various systems and processes for managing construction risks exist in the literature and industry and this section reviews the three key models among these systems and the processes involved, in order to provide a background to the risk management approach adopted in this study.

<u>The Risk Management Cycle (RMC)</u>: Perhaps the model of risk management within the construction industry is what is referred to as the risk management cycle characterised by the three-step process of risk identification, risk analysis and risk response (Raftery, 1994, Buchan, 1994). Implicit within this tree-step system is an initial phase of project definition or initiation during which the project is defined in a form appropriate for the risk management (Chapman & Ward, 1997). *Risk identification* is the stage where the risks and uncertainties that could befall the project are catalogued and their nature studied. *Risk analysis* entails the examination of individual or combinations of risk and uncertainties to obtain quantified values of their potential impact on various aspects of the project in order develop appropriate responses to the potential risks and uncertainties. The *Risk response* stage encompass the development and application of those planned actions necessary to eliminate or control the risks and uncertainties in a manner that ensure the optimal achievement of project objectives.

Flanagan and Norman (1993) present a four-step model for risk management that is similar to the model reported by Raftery (1994) but distinguishes risk classification as a separate process from risk identification. However, if the objective of risk identification is to identify and understand the nature of the risks that a project is subjected to, then risk classification should be a necessary part of the risk identification process. The same model used in Nummedal *et al.*, British Standards BS 8444 (BSI, 1996) and Baker *et al.* (1999) present a five step process of risk identification, risk estimation, risk evaluation, risk response and risk monitoring. Although this model is simplistic, it helps in focusing the risk management effort in a systematic way. Its use is reported extensively in the literature (see also Dey, 2002; Ranasinghe, 1994a,b; Ranasinghe & Russell, 1992; Hayes *et al*, 1986 and Pouliquen, 1970;)

Project Risk Analysis and Management (PRAM): The PRAM approach to risk management was one that seeks to combine project managers' expertise into a practical and yet non-prescriptive process for project risk management. The PRAM system deals with project risk management from the client perspective through a nine-phase structure which starts with a *Define* phase through *Focus, Identity, Structure, Ownership, Estimate, Evaluate* and *Plan,* to *Manage.* The purposes and outcomes of each phase are described by Chapman & Ward (1997) and are presented below in Table 2.4.

Table 2.4: The PRAM Model (Source: Chapman & Ward, 1997)

Phases	**Purposes**	**Deliverables (may be targets not achieved initially)**
Define	Consolidate relevant existing information about the project. Fill in any gaps uncovered in the consolidation process.	A clear, unambiguous, shared understanding of all relevant key aspects of the project and the associated Risk Management Process (RMP), documented, verified and reported.
Focus	Scope and provide a strategic plan for RMP. Plan RMP at an operational level.	A clear, unambiguous, shared understanding of all relevant key aspects of RMP, documented, verified and reported.
Identify	Identify where risk might arise. Identify what we might do about this risk, in proactive and reactive responses terms. Identify what might go wrong with our responses.	All key risks and responses identified, both threats and opportunities, classified, characterised, documented, verified and reported.

Table 2.4 *(Continued)*

Phases	**Purposes**	**Deliverables (may be targets not achieved initially)**
Structure	Test simplifying assumptions. Provide more complex structure when appropriate.	A clear understanding of the implications of any important simplifying assumptions about relationships between risks, responses and base plan activities.
Ownership	Client/contractor allocation of ownership and management of risks and responses. Allocations of client risks to named individuals. Approval of contractor allocations.	Clear ownership and management allocations, effectively and efficiently defined, legally enforceable in practice where appropriate.
Estimate	Identify areas of clear Significant uncertainty. Identify areas of possible significant uncertainty.	A basis for understanding which risks and responses are important. Estimates of likelihood and impact in scenario or numeric terms, the latter including identification of assumptions or conditions, sometimes with a focus on 'show stoppers'.
Evaluate	Synthesis and evaluation of the results of the estimate phase.	Diagnosis of all important-difficulties and comparative analysis of the implications of responses to these difficulties, with specific deliverables such as a prioritised list of risks, or a comparison of base plan and contingency plans with possible difficulties and revised plans.

Table 2.4 *(Continued)*

Phases	Purposes	Deliverables (may be targets not achieved initially)
Plan	Project plan ready for implementation and associated risk management plan.	1. Base plans in activity terms at the detailed level required for implementation, with timing, precedence, ownership and associated resource usage/contractual terms where appropriate clearly specified, including milestones initiating payments, other events or processes defining expenditure, and an associated base plan expenditure profile. 2. Risk assessment in terms of threats and opportunities, prioritised, assessed in terms of impact given no response is feasible and potentially desirable, along with assessment of alternative potential reactive and proactive responses. 3. Recommended proactive and reactive contingency plans in activity terms, with timing, precedence, ownership and associated resource usage/contractual terms where appropriate clearly specified, including trigger points initiating reactive contingency responses and impact assessment.
Manage	Monitoring, Control, Developing plans for immediate implementation.	Diagnosis of a need to revisit earlier plans, and initiation of re-planning as appropriate, including on a regular basis specific deliverables like the monitoring of achieved performance in relation to planned progress, and prioritised lists of risk/response issues. Exception (change) reporting after significant events and associated replanting.

One of the key strengths of the PRAM approach as outlined in the PRAM guide is that it provides an integrated and holistic approach to risk management that clearly describes specialist techniques for identifying, analysing and managing risks.

Risk Analysis and Management for Projects (RAMP): The RAMP methodology is a comprehensive and systematic process for identifying, evaluating and managing risks in capital investment projects published jointly by the Faculty and Institute of Actuaries and the Institute of Civil Engineers in 1998. The aim of the RAMP approach to risk management was to pool the knowledge, skills, experiences and practices of both the actuarial and engineering industries regarding risks, to present a risk analysis and management process which was beyond the methods in common use by any one of those industries. The RAMP process consists of four major activities each of which is multi-phased in content. The details of the process are described in Table 2.5 below.

Table 2.5: The RAMP Process (Source: ICE *et. al.*, 1998)

Activity	Phases	Process Steps
A: Process launch	1. Plan, organise and launch RAMP process	• confirm perspective • appoint risk process manager and team • define investment brief • determine timing of risk reviews • decide level and scope of RAMP • establish budget for RAMP
	2. Establish baseline	• objectives and key parameters of investment • baseline plans • underlying assumptions
B: Risk Review	1. Plan and initiate risk review 2. Identify risks 3. Evaluate risks	
	4. Devise measures for mitigating risks	• Reducing • avoiding • Eliminating • transferring • Aborting • pooling • Insuring • reducing uncertainty • define mitigation strategy
	5. Assess residual risks and decide whether to continue 6. Plan responses to residual risks 7. Communicate mitigation strategy and response plan	
C: Risk management	1. Implement strategy and plans	• integrate with main stream management • manage the agreed risk mitigation initiatives • report changes
	2. Control risks	• ensure effective resourcing and implementation • monitor progress • continually review and categorise trends • identify and evaluate risks and changes • initiate risk review If necessary.

Table 2.5: *(Continued)*

Activity	Phases	Process Steps
D: Process Close-Down	1. Assess investment outrun	• consider results of investment against original objectives • compare risk impacts with those anticipated.
	2. Review RAMP Process	• assess effectiveness of process and its application • draw lessons for future investments • propose improvements to process

Despite the differences in the number of phases and terminologies involved in the risk management process for each system, the three key systems and associated processes are very similar in content and detail. How the stages in the various systems compare is indicated in Table 2.6 below. Note again that the details of the total process are very similar across all three systems, even though a system may not have an explicit definition for a particular detail. For example, although there is not explicit definition of an "ownership" phase under either the RMC or RAMP systems, the tasks of the Ownership phase are achieved in the "Identification" and "Risk review" stages of the two systems respectively. All three systems are useful in ensuring a logical and systematic process for dealing with project risks. The author contends, however, that the 3-step approach of the RMC methodology is deceivingly simplistic. The PRAM approach presents a process structure that clearly defines units of homogenous or related activities that make the process easier to manage when compared to the RAMP methodology. However, the focus of the present study is on the analytical phase of the risk management process and the results of the study will be applicable across all three and any other systems for managing project risks.

Table 2.6: Comparison of Risk Management Systems

RMC	PRAM	RAMP
• Define *(implied by system)*	• Define • Focus	• Process launch
• Identification	• Identify • Structure • Ownership	• Risk Review
• Analysis	• Estimate • Evaluate	
• Response	• Plan • Manage	• Risk Management • Process Close-down

2.3 Types of Risk Assessment

Three main types of risk assessment emerge from the literature. The In-house Individual Expert Assessment assigns the tasks and responsibility for risk identification and analysis to one individual in the company. In the In-house Multi-disciplinary/Panel Group Assessment approach, the tasks and responsibility for risk identification and analysis are assigned to a multi-disciplinary team of experts who work together on the various phases of the risk management exercise. The In-house Synectic Team approach is similar to the In-house Multi-disciplinary/Panel Group Assessment approach, except that it involves the use of a carefully selected team of best-qualified individuals within an organisation to deal with organisation-specific problems on a full-time basis.

2.4 Methods for Identifying Project Risks

Ansell (1992) argues that one of the major problems in evaluating the risk of a system is the identification of the full range of risks to which the system could be subject. The identification process is made difficult especially since what is considered "risk" is significantly influenced by perceptions that are very dynamic in nature. A thorough identification of both internal and external project-related risks requires that the risks analyst is not only systematic and experienced, but also creative. Raftery (1994) argues that the best way to gain access to such a range of qualities is to use a team of experienced construction professionals or experts. Such a thorough identification of risks prior at the early stage of the life cycle is important for a number of reasons. First, the early stage of the life cycle is the stage when most of the major decisions regarding the project and project objectives (such as budget, duration, procurement and contractual system, etc) are made. All of these decisions are directly affected by the potential risks that the project will face. Secondly, the process focuses attention of the project parties on the strategies for the control and distribution of risks and thus on the choice of contract strategy for the project.

Methods for identifying risks in construction projects are very well described in the literature (Chapman and Ward, 1997; Rafter 1994; Flanagan and Norman, 1993; Godfrey, 1996) and are summarised below.

Pondering or "What can go wrong" analysis: The identification process usually starts with an analysis of everything that can go wrong on the project or a project activity. Pondering is a simple risk identification approach in which a single individual carefully and critically analyses the project in order to identify risks or risk responses. This is best achieved using the project plan and developing lists of what can wrong in each activity on the project plan. For example, in the construction of the super structure of a house, collapse of formwork is one of a number of things that can go wrong with the construction of the external walls or cladding.

Free and Structured brainstorming: This is the process where members of the project team come together to highlight and record what each believe could go wrong with the project as the risks come to mind. It is a process of "thinking the unthinkable" and improves the risk identification effort by highlighting more of the possible risks and providing unusual responses to risks (Chapman and Ward, 1997). The free brainstorming stage would pave the way for a more structured approach where the risks can be identified in accordance with the development of the project as outlined in the project plan. A facilitator will normally be appointed to manage the process, and it is recommended that the size of the team does not exceed five (Godfrey, 1996).

Synectics: Synectics is a general technique involving the use of a carefully selected team of best-qualified individuals within an organisation to deal with organisation-specific problems on a full-time basis. The first step in the process involves gaining a thorough understanding of the problem on hand and its implications. The second step involves using various means to view the problem from an unfamiliar perspective.

Risk records: One of the advantages of systematic risks management is that it generates records of risks that can serve as the objective focus for the next risk management effort, by helping to determine the more frequent sources of risk. Such records include both those held by the construction client or contractor, and those held by external agencies such as the Health & Safety Executive.

Prompt Lists: Prompt are keywords associated with various stages of the project that trigger the identification of project related risks. For example, Competence is a prompt that can bring to the mind the risk of contractor or sub-contractor incompetence or bad performance. Archaeological on the other hand can trigger the identification of the risk of delays associated with building on a historical site or uncovering some historical artefacts during excavation. In addition, the list developed from the "what can go wrong" analysis can be used as prompts for developing a more comprehensive list of potential project risks. The essential objective of using prompt lists is to be able to identify risks that are not so obvious. Checklists are thus not effective prompts, since they only state the obvious (Godfrey, 1996).

Structured/Expert Interviews: Structured interviews are particularly useful where the expert input is considered essential to the risk identification effort. This is invariably the case in international projects. Chapman and Ward (1997) argue that since individual experts may not have the breadth and depth of experience covering every aspect of the project, it is important to involve a wide range of experts concerned with the various aspects of the project (designers, engineers, construction/project managers, contractors, etc.) in the interviewing process. This will help to ensure the development of a comprehensive list of risks.

The identified risks would normally be recorded in a risk register that would form the basis for the other phases of the risk management system

2.5 Techniques for Analysing Contractual Risks in Construction

As an aspect of management science, risk management (analysis) techniques fall into two broad categories: deterministic techniques, which assume that values of decision variables can be known with complete certainty (rarely happens in construction!), and probabilistic or stochastic techniques that deal with decision variables that have variability in the values they can assume. Risk analysis techniques can also be categorised into those that aim at looking at the "big picture" rather than specific details of the risks (usually useful during the risk identification/response phases), and those that focus on specific risk areas and provide more detailed analysis (useful for detailed risk analysis of specific risks). In line with the objectives of the current research, this section focuses on a critical review of key analytical techniques that are applicable during the detailed risk analysis stage of the risk management system. The techniques presented here are not exhaustive, but reflect the key models that are commonly used on construction projects. For example, although Fuzzy Set Analysis is reported in the literature and used in construction, Simister (1994) reported that although techniques such as catastrophe theory, Fussy Set Analysis, Game theory and Multi-Criterion Decision Making models were known by most practitioners in the UK, these techniques were either not used at all or used by only a handful of practitioners. These findings are somewhat consistent with the results of the worldwide survey by Burchett *et al.* (1999) and with the findings of this research (see chapter 4).

Sensitivity Analysis: Sensitivity analysis is a deterministic modelling technique used to measure the impact of a change in the value of an input variable about which there is some uncertainty, on the outcomes of the dependent variable such as the project. Used in project risk analysis, its aim is not to quantify risks but to identify which components of a project have the greatest impact on the project outcome and therefore what are the main components to be considered in detailed risks analysis. For example, assume that inflation and access to site are risk items in a project and the value of inflation could be lie in the range of 1% to 3% while access to site could be delayed for up to 5 months. Sensitivity analysis seeks to answer the question "*what would be the impact on project price if inflation went up by 1%, 2% or 3%?*", and similarly, "*what would be the impact on project price if access to site was delayed by 1, 2 or 3 months?*"

One of the keys advantages of sensitivity analysis is that it is quick and easy to use and require little data. Furthermore, even though it is a deterministic method, it recognises the uncertainties associated with the input variables and show how the project will be affected by changes in the input variables. However, the method does not consider the likelihood of the range of input or output values, and therefore does not give a true probabilistic picture of the variables, in spite of its recognition of the uncertain values of the variables. It also pays no attention to risk attitudes and perceptions, and how such personal attributes affect estimates of the values of input variables.

Decision Tress Analysis: Most major projects are characterised by a series of either/or decisions that present several different routes to achieving the same goal. These routes present a variety of investment possibilities and a sequence of decision choices that need to be carefully analysed in order to find out which route or decision choice best meets project objectives. A Decision Tree is a graphical model that uses tree-like structures with branches to represent the sequence of decisions (representing current possible courses of action or combinations of actions) and the expected outcomes for each possible route. Each outcome is given a probability value that represents the likelihood of occurrence. Applied to risk analysis, the decision tree therefore logically structures the approach to risk management by identifying alternative responses to mitigating risk (Dey, 2002). Two broad types of the decision tree approach are reported in the literature. The first is the traditional deterministic model (in which deterministic estimates are used to represent variable values and likelihood of outcomes). The second is the stochastic model (originally developed by Hespos and Strassman (1965)), which combined the logic of decision trees with Monte Carlo simulation and in which all decision factors with variability in values (and consequently investment outcomes) can therefore be represented by continuous, empirical probability distributions.

Advantages of the decision tree technique include the fact that it forces the decision maker to recognise the existence of certain basic elements in the structure, and provides a consistent and objective structure to developing a decision strategy (Flanagan & Norman, 1993). The stochastic model has the added advantage that it recognises that most input variables and outcomes of investment decisions have a large number of interrelated values that cannot be accurately represented deterministically.

Probability Analysis/Monte Carlo Simulation: Probability analysis of risk assumes that decision input variables subject to risk and uncertainty can be described by probability distributions, and aims to overcome the weaknesses of sensitivity analysis by recognising explicitly that all risk and uncertainty can be expected to vary simultaneously (Flanagan & Norman, 1993). It therefore specifies a probability distribution for each risk or uncertainty and then considers changes in the risk/uncertainty in combinations (Hayes *et al.*, 1996). Thus, rather producing discrete values of the outcome, the result of a probability analysis is a range of values over which the outcome could lie. Perhaps the most easily used technique for calculating the probabilities with which the possible outcomes can lie is Monte Carlo simulation. In this method, the range of values for each risk being analysed is determined together with the probability distribution that best describes each risk. A value for each risk is randomly selected (from within its specified range and probability distribution) and the outcome of the project calculated using the combination of values selected for each one of the risks. The calculation is repeated a number of times (based on the degree of confidence required - usually between 100 and 1,000) to obtain the probability distribution of the project outcome (Hayes *et al.*, 1996).

One of the key advantages of the probability analysis and therefore the Monte Carlo approach is the ability to use probability distributions based on both objective and subjective data (Chau, 1995; Flanagan & Norman, 1993). The drawback o the Monte Carlo approach is the tendency for analysts to focus on the overall impact of risk combinations on the project to the point of losing the importance of dependency, or to ignore the intermediate stages of the analysis (Chapman & Ward, 1997).

While all the above methods are useful for risk analysis at different stages of the project, none has been applied to the analysis of contractual risks with sufficient rigour. The deterministic approaches are unsuitable because of the wide range of values that most contractual risks can assume. Although the probabilistic approaches are the most suitable to contractual risks, they have at best often been used with triangular distributions for risks that are subjective in nature (Flanagan & Norman, 1993). The author argues that this lack of rigorous application is due to the lack of an effective method for capturing the wide range of subjective probabilities presented by contractual risks into representative probability distributions than can be used as input variables for rigorous probability analysis.

2.6 Types of Risk Responses

Risk response measures fall into two broad categories: advanced planning actions designed to control the likelihood and/or impact of the risks, and risk containment actions. The latter are undertaken while the project is in progress and which are designed to bring the adverse risk impact as close to zero as possible, and/or seek opportunities to development a net gain out of the occurrence o the risk.

2.6.1 Advanced Planning Actions

Risk Avoidance: This is synonymous to modifying corporate or project objectives. At a project level, this can take the form of a contractor dropping out of the competition for the project, or a client discontinuing with a project or contract (e.g. in the case of a breach of contract by a contractor). Such risk avoidance would normally be a sound business decision when loss potential clearly outweighs the profit potential (opportunity).

However, the more likely to be the case during risk management that consideration will be given avoiding specific risks (whether during project planning, pre-contract negotiations or project execution) in order to make the project or contract viable.

Risk Mitigation/Reduction: Risk mitigation involves taking decision choices and actions that have the benefit of reducing the likelihood, reducing the impact of the risk and/or modifying the nature of the risk by transforming an impact on one resource target on to another. For example, the risk of project delay that could be caused by impending adverse weather may be mitigated by paying for over-time work during good weather conditions.

Risk Prevention: Analysis of risks may reveal decision alternatives that carry reduced loss potential. One such alternative is risk sharing with other parties (as seen in joint venture arrangements, Partnering, or the use of worker incentive programs). Another example of risk sharing is a target cost/work-hour contract where risk is usually shared through a formula that splits overruns and underruns. Risk reduction or prevention can also be achieved through buildability analysis. For example, a buildability analysis may replace planned field assembly of some components with shop prefabrication to prevent or reduce potential delays due to adverse weather conditions.

Risk Transfer: Another option is to transfer the risks, ideally to the party that can best manage or absorb the risk. The objective in risk transfer is to change an uncertain exposure into a certain cost. The commonest form of risk transfer is insurance in which an insurance company receives a defined premium in exchange for absorbing the financial impacts of a risk. For example, the potential losses associated with many project risks are often insured through Workers' Compensation, Bodily Injury and Property Damage Liability, Builders' Risk and other policies. When insurance policies contain deductible amounts in addition to the premiums, the deductibles represent a level of self-insurance or "potential uninsured losses" risk items in the contract.

Risk Acceptance with Contingency: This involves making a conscious decision to accept a risk and to set aside resources (the "contingency" - expressed in dollars, physical resources and/or time) that would provide a reactive capability to cope with the impact of the risk should it occur. Thus, the sum of planned profit plus contingency dollars in a contract represents the contractor's total ability to absorb losses without experiencing a net loss on the project.

Risk Acceptance without Contingency: Sometimes competitive bidding conditions will preclude the inclusion of a large contingency in a contract and some risks may need to be accepted without contingency. Such risks would ideally be ones that have low impact value, contain a low probability of occurrence for which the cost of risk transfer would be uneconomical.

2.6.2 Risk Containment Actions

Even after careful review of the risks, the estimates of risk are just that - *estimates.* Thus, the risks are neither inevitable, nor are their likelihood or impact values set in stone. Effective risk management must thus include strategies for risk containment aimed at converting some or all of the project contingencies into additional profit. Typical risk containment actions include the following:

Contingency Planning: By planning for both normal and contingency events, response to adverse situations can be expedited and their effects minimised.

Qualified Personnel and Sub-contractors: Although it is expected that the project parties will always use qualified personnel on the project, the use of known, experienced personnel, extremely selective recruiting, and formal training where required is critical to best assuring the effective containment of risks in any situation. Using pre-qualified subcontractors will help to ensure that the work meets quality and time requirements and not adversely affect other activities.

Safety and Security Program: A strong safety and security program will not only minimize human and material losses on a project and consequently lower Workers' Compensation costs on future projects, but also contribute to higher morale and better productivity.

Delegation of Risk Control Responsibility: Responsibility for the control of risk would be assigned to the individuals or organizations with the greatest capability to control that risk along with a requirement for regular status reporting.

Strong Project Controls and Critical Items Reporting: Adequate project controls should be in place to provide timely and accurate reporting and analysis the staff to enable the identification of actual and potential problem areas in time for positive corrective action. A system should also be established for special reporting of any situations that has affected or has the potential for significantly affecting cost or schedule so that these items can receive special attention.

Project Labour Agreement: On union projects and in cultures with unstable labour relations, such agreements can eliminate adverse working practices, enhance labour efficiencies and help maintain harmonious labour-management relations.

Rehearsals: For critical operations, rehearsals will reduce the potential for errors during the real operation.

2.7 Summary

The aim of this chapter was to enhance understanding of risk and risk management by providing a clarification of the concept of risk and its various ramifications, and a review of the current body of written work on risk applicable to this study. Starting with a clarification of the definition of risk, the chapter therefore discussed the essential components of risk, and discussed how the various ways in which risk is classified help to understand the nature of risks both in general and business terms, and with specific application to construction project risks. Drawing on existing work on construction risk classification, the chapter produced a detailed classification of international construction project risks. This classification recognised not only the different levels of risk sources that affect an international project, but also the types of risks that each source can generate, what project resource(s) that are likely to be impacted by the risks should they occur and what could be the potential nature of the impact. Such a classification provides a much better understanding of the nature of construction project risks than has been previously reported in the literature.

The second section of the chapter looked at the key systems and processes for managing construction project risks and compared the systems presented by the Risk Management Cycle (RMC), PRAM and RAMP in further detail. Sections three to five provided a detailed review of the essential stages of the risk management process, form risk identification through risk analysis to risk response. In line with the objectives of the research, the study looked critically at the key deterministic and probabilistic approaches to risk analysis and how the current approaches fail to capture the wide range of subjective probabilities presented by contractual risks, as representative probability distributions than can be used as input variables for rigorous probability analysis.

The next chapter presents a critical review of the literature on subjective probability and techniques for eliciting subject expert opinions as input variables for the analysis of risks and uncertainties. It also discusses how the underlying assumptions and principles of these techniques apply to contractual risks, and therefore how these techniques can be used to capture and transform subjective estimates of probabilities into representative probability distributions than can be used as input variables for rigorous probability analysis of contractual risks.

CHAPTER 3

ELICITATION OF SUBJECTIVE PROBABILITIES FOR RISK ANALYSIS

3.0 Elicitation of Subjective Probabilities: Theories, Heuristics and Techniques

Like risk, the concept of probability dates as far back as the era of primitive human societies where, for example, dreams, omens, etc. were used (as they still are to some extents today) as decision-making tools for providing guidance for the future. Dreams and the like were interpreted deterministically - the event would either happen or it would not - and by establishing the probability of the event ahead of time, humans were able to work around the perceived odds whether good or bad. The book of Genesis in the Holy Bible, for example, records how Joseph interpreted the dreams of Pharaoh, King of Egypt, regarding seven years of great agricultural harvest that were to be followed by seven years of great famine. By embracing the interpretations of the dreams, Pharaoh and the nation of Egypt made provisions for the future that saved them from the starvation that came with the seven years of famine. As an organised theory, however, the roots of probability can be traced to the French philosopher and mathematician, Blaise Pascal, who was intrigued by the challenge of winning a game of chance and set out "*to reduce to an exact art, with the rigour of mathematical demonstration, the incertitude of chance, thus creating a new science which could justly claim the stupefying title: the mathematics of chance*" (Wagner, 2001). The description of probability as "*... the very guide of life*" by Bishop Joseph Butler in 1736 (Kyburg, 2001) was thus not only applicable to gamblers who had a few bills of money to lose or gain, but also to people and whole societies whose very survival was at stake.

Probability theory has evolved considerably into mathematically systemized tools since the days of Pascal, although the number of conflicting interpretations of probability persists. One strand of these conflicting interpretations is the subjective probability school that, although offers tremendous potential for application in contractual risk analysis, presents a number of challenges, due to the subjectivity of the estimates. These challenges have created many divides among mathematicians and theorists and practitioners of risks and uncertainties analysis. To understand the suitability and applicability of subjective probability to construction risk analysis, it is important to grasp not only the concept of probability generally, but the concept of subjective probability in particular and how it can best to encoded in a manner that makes their use suitable for analytical purposes. This chapter briefly discusses the nature of probability and reviews of the literature on subjective probability and techniques for eliciting subject expert opinions as input variables for the analysis of risks and uncertainties. The aim is to present the theoretical and practical framework upon which the model for generating subjective probabilities for systematic analysis of contractual risks is based.

3.1 The Nature of Probability

Controversy exists today among statisticians regarding the empirical nature and interpretations of probability as they did during the beginnings of its formal roots. In broad terms, these conflicting views can be classified into three main strands. The first involves aspects of long-run frequencies and is often referred to as the relative frequency view. The second view involves aspects of logical entailment or evidence and is referred to as the logical probability view. The third school involves aspects of personal belief and represent the subjective probability view. (Kyburg, 2001; Chelsey, 1975).

The relative frequency concept tended to be the most familiar concept until recently, having gained a head start of several decades as part of the development of the traditional or classical school of statistics. In the relative frequency concept that is commonly ascribed to Venn, probability is considered as "the limit of a sequence of relative frequencies of occurrences of a stated property among elements of a specified set of elements called a reference class" (Chelsey, 1975). Hampton *et al.* (1973) define this probability as "the limiting value of the relative frequency of the event concerned as the number of trials, in which the event concerned is one possible outcome, increases indefinitely". In the application of this classical concept to probabilistic prediction, a prediction equation, relating Y_t (the value of the predicand at some future time, t) directly to X_o (the values of the predictor variables at the initial time) is derived from past observational data and then applied to the situation at hand (Murphy and Winkler, 1984). To the traditional statistician therefore, probabilities are objective because they are related to observable events through the limit of relative frequency, i.e., the relative frequency of the occurrence of an event after an infinite number of similar trials have occurred. In the words or theorem of James Bernoulli, "in the long run, the relative frequency of an event approaches its probability" (Phillips, 1973). However, the use of relative frequencies as the sole basis for prior probabilities has inherent problems. First, the relative frequencies of past events may not be necessarily applicable to future events. Secondly, the lack of definition for the requirement for "similarity" of trials/events introduces a subjective element of its own into a supposedly objective definition. There is also the need for the subjective selection of distributional forms. Furthermore, there is a limitation on the applicability of the concept of relative frequencies to only repetitive events since for unique or rare events there would be little or no historical data from which to derive relative frequencies. To make the relative frequency concept applicable to such non-predictable events, there will have to be the subjective postulation of the existence of a relative frequency (Fishburn, 1964).

The logical probability view evolved out of philosophical induction and "*... holds that probability measures the extent to which one set of propositions, out of logical necessity and apart from human opinion, confirms the truth of another*" (Savage, 1972). The first detailed discussion of the logical probability view is attributed to Rudolf Carnap (Carnap, 1950). Carnap showed that if a non-negative additive probability measure with a maximum value of 1 is defined over all the sentences of a language on logical grounds, then conditional logical probabilities could be expressed as the ratio of these measures. Thus, the probability of sentence h, given total evidence e is the ratio of the measure of $h|e$ to the measure of e. According to John Keynes of this view and arguing partly from an analogy to the construct of similarity and partly from the view that probability represented a logical entailment between a hypothesis and the relevant evidence, probability was only partially ordered. Partial ordering means that it cannot always be said of two hypotheses A and B that $P(A) > P(B)$ or that $P(A) < P(B)$, or that $P(A) = P(B)$. Furthermore, even If one could judge that which of $P(A)$ and $P(B)$ is greater, one may not be able to judge by how much one is greater because the probabilities $P(A)$ and $P(B)$ may just be incomparable (Keynes, 1952, Budescu & Wallsten, 1987; Kyburg, 2001). Proponents of this view have had very little agreement regarding what a reasonable probability measure on the sentences of a formal language might be. Fine (1973) reports that the difficulty in arriving at a universally acceptable value for the degree to which the available evidence confirms the given hypothesis has resulted in the empiricism of this concept being restricted to specific languages that cannot describe the profusion of scientific observation. Kyburg (2001) reports that even Carnarp, perhaps the most dedicated enthusiast of the logical probability view, lost his faith in this view and drew closer to the subjective interpretation of probability towards the end of his life.

Savage (1972) defines subjective probability as "*a measure of the confidence that a particular individual has in a particular proposition*". Unlike the other views about probability, this approach does not attempt to evaluate what assessments are "correct" but admits all self-consistent or coherent assessments that the assessor confirms as corresponding to his/her judgments. The development of this view can be traced to Frank Ramsey (Ramsey, 1931) and Bruno de Finetti (de Finetti, 1980). One axiom of the subjective probability concept that is attributed to the work of Bruno de Finetti (1964) is the personalistic or individualistic theory in which subjective probability represents the extent to which a coherent person believes a statement to be true based on all the information available to him/her at that time. Subjective probability then, is considered in this view as a quantification of uncertainty and (Hampton *et al.*,1973). Winkler (1967a), Chelsey (1975), and Wallsten & Budescu (1983), assert that this degree of confidence can be "*expressed intuitively in terms of betting odds or translated, if desired, from odds to probability*". Chelsey (1975) and Wallsten & Budescu (1983) distinguish a second empirical axiom of subjective probability developed by Koopman and Good and called the intuitive comparative school. This view follows either a likelihood-based system or a preference-based system. The likelihood-based system yields an additive probability measure by specifying conditions that must be satisfied by a set all of whose events are put in a single transitive or weak order by the relation "not more likely/probable than". The preference-based system yields a probability measure of events and a utility measure of outcomes by specifying conditions that must be satisfied by a set of gambles or lotteries weakly ordered according to the relation "not preferred to" (Wallsten & Budescu, 1983).

3.2 Bayes' Theorem, Subjective Probability and Contractual risks

The interpretation of probability as a matter of personalistic and subjective belief is the basis of the Bayesian approach to probability analysis. The origin of Bayes' Theorem is attributed to Thomas Bayes, the former University of Edinburgh student, amateur mathematician and nonconformist Presbyterian Minister whose essay: *An Essay Towards Solving a Problem in the Doctrine of Chances* published by the Royal Society in its Philosophical Transactions in 1763 (two years after his death) shaped the nature of Statistics (Norland & Stabile, 2000). The crux of the essay was to determine the chance that the probability of an unknown event happening in a single trial would lie between any two degrees of probability that can be named, given the number of times that the event has happened and failed in the past.

LaPlace, the French Mathematician, and others later used the idea of conditional probability to capture Bayes' approach and generalise it into what is now known as Bayes' Theorem. Bayes theorem starts with the precept that through frequency observations we are able to determine the probability of an effect occurring and that we are similarly able determine the conditional probability of the effect given its cause by observing the number of times the cause had exhibited that same effect. We can then determine the "reverse" or *posterior* probability of the cause from the effect (Vick, 2002). Thus if we let

$$
\begin{aligned}
P[cause] &= \text{probability that the cause occurs} \\
P[effect] &= \text{probability that the effect occurs} \\
P[effect|cause] &= \text{conditional probability of the effect given the cause} \\
P[cause|effect] &= \text{conditional probability of the cause given the effect,}
\end{aligned}
$$

Then Bayes theorem in simple terms is stated as:

$$P[cause|effect] = \frac{P[effect|cause].P[cause]}{P[effect]} \qquad \text{(Equation 3.2.1)}$$

from which we also have

$$P[effect|cause] = \frac{P[cause|effect].P[effect]}{P[cause]} \qquad \text{(Equation 3.2.2)}$$

For example, a fair coin has a 50%-50% chance of coming up heads when tossed. However, what if one was not certain that the coin was fair? To solve this problem, the frequentist would conduct a large number of coin flipping trials and record the percentage of times that the coin came up heads. The frequentist then constructs a confidence interval based on an arbitrarily selected degree of certainty (usually 95%). If 50% of the results lie outside this interval, then one can reject the null hypothesis that the coin is fair. However, if 50% lies within the interval, then one cannot reject the null hypothesis that the coin is fair. Bayesian statistics on the other hand argues from observed events to derive the probability of their causes. Bayes approach would thus seek to answer the question: based on the sample information $P[effect]$ and any prior knowledge what is the chance that the probability that the coin is fair given that a toss resulted in a head (i.e. $P[cause|effect]$) lies between any two points that can be named? Expressing the problem in mathematical notations, if we represent

(a) the probability that the coin is fair by $P(\theta_1)$ and that the coin is unfair by $P(\theta_2)$ (i.e., θ_1 and θ_2 represent the "causes" for a toss resulting in a head)

(b) the probability that a toss results in a head (i.e., the probability of the "effect" *x*) by $P(x)$. This represents the sample evidence of the total number of coin flips resulting in a head irrespective of the condition of the coin (fair or unfair) that causes a coin flip result of a head.

(c) the probability that the coin is fair given that a toss resulted in a head by $P(\theta_1|x)$ and that the coin is unfair given that a toss resulted in a head by $P(\theta_2|x)$

(d) the probability that a toss will result in a head if/given that the coin is fair by $P(x|\theta_1)$ and that the coin is unfair given that a toss resulted in a head by $P(x|\theta_2)$

then

$$P(x) = P(\theta_1).P(x|\theta_1) + P(\theta_2).P(x|\theta_2)$$

$$= \sum P(\theta_i)P(x|\theta_i) \qquad \text{(Equation 3.2.3)}$$

and

$$P(\theta_1|x) = \frac{P(x|\theta_1)P(\theta_1)}{\sum P(\theta_i)P(x|\theta_i)} \qquad \text{(Equation 3.2.4)}$$

Similarly,

$$P(x|\theta_1) = \frac{P(\theta_1|x)\sum P(\theta_i)P(x|\theta_i)}{P(\theta_1)} \qquad \text{(Equation 3.2.5)}$$

The power of Bayes Theorem becomes even more apparent when applied to contractual risks. Suppose that on an international construction project one was interested in finding out whether a delay in project completion (effect) will result if there is a payment delay (cause) by the host government. A number of factors including payment delays by the host government or sponsor, delays in access to site, labour unrests, etc. can result in the project missing its target completion date. Of course, there also times when payment delays (or the other factors for that matter) do not necessarily result in project delays. If we represent the probabilities associated with payment delays by $P(\theta_1)$ and the other factors or sources of the risk of project delay by $P(\theta_2),....P(\theta_n)$, represent the probabilities of a project delay (event "x") resulting from the occurrence of these causes of project delay (i.e., their "true-positive" probabilities) by $P(x|\theta_1), P(x|\theta_2)$, ... $P(x|\theta_n)$, and determine $P(x)$, the number of times project delays have occurred on a specified number of similar international projects over a period of time irrespective of the cause (say this is 0.65 based on sample evidence representing the ratio of the sum of all the projects in which there were project delays in the given period to the total number of projects over the same period), then from Equation 3.2.3,

$P(x)$ = *P*(project delay)

= *P*(project delay if there is a payment delay by the host government) + ... + *P*(project delay if there is a delay in access to site)

$= P(\theta_1) . P(x|\theta_1) + ... + P(\theta_n) . P(x|\theta_n)$

$= \sum P(\theta_i) P(x|\theta_i)$

$= 0.65$

In addition, we are able to determine $P(\theta_1|x)$ (the probability of a payment delay given that there is a project delay, or the probability that a project delay was or would be caused by a payment delay) by how often we find that there was a payment delay in projects that had delayed completion over the same period in which we had the 65% project delays. Say this happens 75% of the time, then from Equation 3.2.4,

$$P(\theta_1|x) = 0.75$$

However, as Equation 3.2.2 indicates, Bayes theorem requires that we know something about the *posterior* probability that we seek (in this example $P(\theta_1)$, the probability of a payment delay) even before bringing the sample evidence into play. Where this *prior* probability comes from is something that Bayes never seem to have worked out himself, but which had been one of the key outcomes of Bernoulli's probabilists' urn experiments with 3000 white and 2000 black pebbles (that if we draw an increasing number of pebbles from the urn, we will eventually arrive at the ratio of 3:2), which led to the development of Bernoulli's Theorem. Bernoulli's Theorem states that "*in the limit as the* *number of drawings N approaches infinity, the probability P that the observed proportions of observations m/N corresponds to the actual proportion p, approaches certainty*". Bernoulli called the actual proportions *p*, the *prior* probability. For Bernoulli, certainty was a moral concept intimately tied to degree of belief and being 98% sure of an outcome was sufficient to achieve "moral certainty" - just as the traditional statistician would have achieved sufficient "statistical goodness" at a 95% confidence level (Vick, 2002). Bayesians therefore argue that the *prior* in Equation 3.2.2 is a *subjective probability*. The argument is that one can always start with a belief regarding the probability of an outcome (*prior* probability), and increase the degree of belief about the value of the probability as new information becomes available. In line with the postulates of subjective probabilities, this approach does not attempt to specify what is a "correct" probability, but accepts all self-consistent or "coherent" assessments of an observer as admissible evidence as long as the individual feels that they are consistent with his/her belief. In fulfilling the requirement for the postulates of coherence, probability assessments would be revised in view of any sample evidence.

Thus, in relation to the issue of project delays discussed above, a construction expert may estimate the probability of a payment delay in the project based on his/her prior knowledge and belief. Say this estimate is given by the expert as 0.85), i.e.

$$P(\theta_1) = 0.85$$

Then the probability of a project delay given that there is payment delay will be given as:

$$\begin{aligned} P(x|\theta_1) &= \frac{P(\theta_1|x)\sum P(\theta_i)P(x|\theta_i)}{P(\theta_1)} \\ &= \frac{0.75 \text{ X } 0.65}{0.85} \\ &= 0.57 \end{aligned}$$

The Bayesian approach is thus based on the mathematics of conditional probabilities and incorporates the decision-maker's prior distributions, $P(\theta_1), P(\theta_2), P(\theta_3), \ldots. P(\theta_n)$ which reflect his/her a priori opinions about some theoretical matter, and likelihood functions, $P(x|\theta_1), P(x|\theta_2), P(x|\theta_3), \ldots\ldots P(x|\theta_n)$, which reflect the sample information on the matter, to form a posterior distribution, $P(\theta|x)$, on which decisions are to be based. It becomes evident from Equation 3.2.4 that the posterior distribution thus summarizes the state of knowledge about an unknown, conditional on the prior and current data, and is proportional to the product of the prior and the likelihood function, with the likelihood receiving more and more weight as the sample size increases (Dunson, 2001).

As discussed in chapter 1, contractual risks are very similar in nature to the types of uncertainties for which subjective probabilities (and Bayesian approaches for that matter) have been applied to their analysis and such methods ought to be applicable to contractual risks analysis in a manner that will enhance analytical rigour and the effectiveness of the risk management effort. Unlike events that form part of a larger population and therefore subject to the laws of large and small numbers (Tversky & Kahneman, 1971, Rabin, 2002), contractual risks often represent isolated or rare event samples for which analysis long-run frequency and traditional statistical approaches are not applicable. Decisions about the possibilities of future occurrences of these events are often made solely based on the decision-maker's experience (or the experiences of his/her expert advisors) from which the probability estimates about the risks events are derived. The problem with the single point estimates from individual experts, however, is that they are often shrouded in perceptions and biases that are often not addressed in during the analysis. Bayesian analysis enables predictions that would otherwise be based solely on an individual's single point estimate to be adjusted by any available sample information. Furthermore, the method by which the experts' estimates are encoded can further reduce the impact of perceptions and biases on the estimates (see section 3.4). These advantages notwithstanding, there have been a number of criticisms of the Bayesian approach.

Phillips (1973) reports on the reluctance of traditional statisticians to adopt Bayesian ideas because prior opinion is not only vague and incapable of being quantified, but also largely meaningless. Mak (1995), drawing on the works of Cohen (1985), Borden (1987) and others, presents a strong criticism of Bayesian applications to construction risk management. Mak argues firstly, that the Bayesian assumptions of mutual exclusivity, exhaustive hypothesis and conditional independence of evidence in hypothesis do not always hold. Mak argues further that the Bayesian view does not allow one to distinguish uncertainty from ignorance in that one cannot tell whether the degree of belief was directly calculated from evidence or indirectly inferred from an absence of evidence.

Thirdly, because the single degree of belief is represented by a point estimate, it is difficult to verify its accuracy. Phillips (1973) and Chau (1995) argue that the issues of vagueness and dependence arise due to the human inability to handle complex events and systems. They thus argue that reliability of the estimates decreases as the event/subsystem increase in size and complexity an that by decomposing such complex events and systems into simple events and subsystems, making judgements about the simple units and reassembling the pieces by probability laws, we can confidently arrive at consistent and meaningful probabilities. The work of Ravinder *et. al.* (1988) supports this assertion and affirms that the decomposition-judgement-reassembly procedure can offer tremendous benefits not only in the reduction of the information processing demands on the judge or expert, but also in reducing the random errors associated with probability encodings. The current author contends that although there may be general issues with distinguishing uncertainty from ignorance in the Bayesian approach generally, this issue is easily overcome in construction risk analysis by the appropriate selection of the sources from whom the probability estimates are elicited. This view is also held by Chau (1995) who contends, in the case of using subjective estimates for construction cost analysis, that estimator's estimates are not random guestimates but based on their experience that includes historical facts, although they may not be recorded systematically in the estimator's mind. He argues further that issues of bias due to differences in individual perceptions and range of experience can be reduced through group estimating techniques such as the Delphi technique. Grayson (1998) also argues for the "fair-bet" justification for quantifying beliefs about a single occasion of an event and contends that although frequentists tend to want to have no dealings with beliefs on single occasions applied in Bayesian probabilities, such belief-probability may arise from relative frequency considerations. The present author contends that inaccuracies arising from the single degree of belief being represented by a point estimate can also be reduced through the elicitation of beliefs from multiple experts in order to generate a distribution for the estimate.

In applying the Bayesian approach to predicting aggregate insurance claims distribution, David *et al.* (1998) also argue against the criticism of the Bayesian approach for its choice of subjective prior distributions. David *et al.* (1998) argue that the use of the Bayesian predictive density to forecast future observations not only does automatically incorporate both process uncertainty and uncertainties due to parameter estimation error, but it is also only natural in that one bases one's predictions on the conditional distribution of the future given the past. These views are shared by other analysts including Cairns (1995), who applies the Bayesian approach to ruin theory's adjustment coefficient, and Hesselager (1993) and Hürlimann (1993, 1995) who apply the Bayesian approach to reinsurance. The argument is perhaps best summed up by Grayson (1998): *we are all doing something like this whenever we claim data-based support for a theory, so why not admit it by quantifying our scientific preconceptions?* Phillips *et al.* (1998) cautions, however, that although Bayesian inference provides a natural and consistent way to make best use of all relevant information for decision-making, its effectiveness depends to a large degree on the reliability of the information obtained.

3.3 Subjective Probability Estimation: Heuristics, Accuracy and Reliability

Invariably, most decisions are made on the basis of beliefs concerning the probability of uncertain events and as result of the lack of models to compute the outcomes of these events, the assessment of uncertainty is often based on the intuitive judgements of human beings (Tversky, 1974). Wallsten and Budescu (1983) argue that the human subject acts as a measurement device (just like a ruler) by mapping various amounts of a particular qualitative property or abstract construct (e.g. subjective uncertainty) into its operational indicant (e.g. expressed preferences or encoded probabilities) in such a manner that specific relations and operations on the indicant reflect corresponding empirical relations and operations on the qualitative property. The basic underlying assumption of this mapping is the existence of a functional relation between the qualitative property and its operational indicant. Tversky (1974) and Wallsten and Budescu (1983) both argue, however, that unlike a measuring device for physical properties that obeys fairly simple and very well studied and understood principles, the nature of the assumed functional relationship or the judgemental operations by which a person assesses the probability of an uncertain event or orders events by their perceived likelihood are not fully known and may not even be constant over situations or individuals. Tversky (1974) suggests three key heuristics (rules of thumb) that dictate the way in which things are perceived and how subjective probabilities are evaluated and predicted. These heuristics contribute to what is described as the decision-maker's cognitive structure. Fisk (2002) argues a fourth key explanation for the subjective probability estimation behaviour of human subjects. These are briefly discussed below.

(a) Judgement by Representativeness: This heuristic argues that to answer many of the probabilistic questions which are of the general types "what is the probability that an object A belongs to a class B?" or "What is the probability that an event A originates from process B?" or "What is the probability that a process A will generate and event B?", people typically compare the essential features of A and B, and assess the degree of similarity between them (or the connotative distance), or the degree to which one of them is representative of the other. A high probability is judged if the similarity or representativeness is very high, and a low probability is judged if the similarity or representativeness is very low.

Biasing errors occur in this approach because, for example, prior probability or base-rate frequency or sample size which would normally affect probability estimation have no effect on representativeness and are thus not taken into consideration by this heuristic which, according to Tversky (1974), are still generally relied upon in intuitive judgements by both laypersons and experts. In another study, Tversky & Kahneman (1983), demonstrated that, when evaluating the probability of the conjunction of two events, most individuals made systematic errors the best known of which is their violation of the conjunction rule in which people ranked the conjunctive statement consisting of one unlikely event and one likely event to be more probable than its unlikely component (Fisk, 2002). The conjunction rule requires that for any two events A and B, $P(A \cap B) \leq P(A)$ and $P(A \cap B) \leq P(B)$. Ranking $P(A \cap B) > P(A)$ or $P(A \cap B) > P(B)$ is thus a violation of this rule. Tversky & Kahneman (1983) referred to this violation as the conjunction fallacy and attributed this error to the use of the representativeness heuristic. According to Kadane & Wolfson (1997), the conjunction fallacy does not apply to expert elicitation.

(b) Judgement by Availability: According to this heuristic, the probability of an event may be estimated by assessing availability or associative distance, that is, the ease with which instances or occurrences can be brought to mind. For example, one may assess the probability of heart attack among middle-aged men by recalling such instances among ones acquaintances.

Flanagan & Norman (1993) argue that although this may indeed be a good measure of probability (since frequently occurring events are more readily recalled), predictable biases do occur in using this approach due to factors such as familiarity, salience, recency or how dramatic the event was. For example, following the September 11, 2001 terrorist attack on the USA, the treat of further terrorism against the USA was perceived by Americans as being imminent. This perception led to a support for an Iraqi war based on what was considered by many in the USA and British Intelligence community as "hyped-up" or "sexed-up" interpretation of intelligence information. When probability has to be assessed by first generating instances according to given rule or by imagining the contingencies with which the event is not equipped to cope, the ease of generating these instances or the imaginability of the contingencies often become the yardstick for evaluating the probability. However, ease of instance generation or imaginability has no bearing on actual frequency.

(c) Judgement By Adjustment: Often the probability of an event may be estimated by starting from an initial value (obtained either through the problem formulation or partial computation), and then adjusting this value to yield the final value. This approach is prone to anchoring errors, as different starting points yield different results that are biased towards the starting value. Chapman & Ward (1997) also argue that anchoring errors may be the explanation for the conjunction and disjunction fallacies in which conjunctive "and" events tend to be overestimated and disjunctive "or" events tend to be underestimated. They illustrate, however, that anchoring biases could be minimised using appropriate approaches for eliciting the subjective estimates.

(d) Judgement by Potential Surprise: Fisk (2002) revisits the works of Christensen, (1979) and Shackle (1969) and argues that another way that individuals might internally represent probabilities is based on what Shackle referred to as 'potential surprise'. According to this theory, all events have the potential to generate surprise to varying degrees and that individuals base their subjective probability judgments on these internal representations of surprise. Events that possess zero surprise value are usually perceived as likely and events that have higher surprise value are considered unlikely. In addition, as an event increases in its potential surprise value, it is perceived to be progressively more unlikely. Fisk argues that the concept of potential surprise is the explanation for Tversky's conjunctive and disjunctive fallacies exhibited by people when making subjective estimates.

Another problem with the estimation of subjective probabilities relates to the extent to which the empirical processes employed to measure the probabilities enable the numbers obtained to provide uniqueness, allow meaningful inferences to be made about the attribute being measured, and represent the attribute being measured (Wallsten and Budescu, 1983).

Cicourel (1964) argues that at any given time, knowledge depends on the particular state of the methods/measurement procedures used. In addition to the practical considerations regarding the use of any methods, the epistemology of the scientific mode of knowledge acquisition raises fundamental issues for evaluating the "accuracy" and "trustworthiness" of the knowledge obtained by that method. Among these fundamental issues of immediate interest to this study are those of the reliability, internal consistency, validity, external validity, construct validity, calibration and generisability of the measurement or scaling process and the conclusions derived.

Reliability - "the degree of consistency of a measurement procedure" (Sedlack and Stanley, 1992, p. 198) gives "an indication of the extent to which the measure contains errors that differed from observation to observation during any one measuring instant, or from time to time for a given unit of analysis measured twice or more by the same instrument" (Nachmias & Nachmias, 1981, p. 144). Reliability is decreased if random error is allowed to enter the measuring process.

Internal Consistency refers to the extent to which the encoded probabilities conform to the laws of probability. Essentially, the criterion compares the encoded probabilities of mutually exclusive events combined in accordance with the laws of probability with encodings of the resulting compound events (Budescu & Wallsten, 1987). For example, probability laws require that for any two events A and B, $P(A \cap B) \leq P(A)$ and $P(A \cap B) \leq P(B)$, while for any two mutually exclusive and exhaustive events, $P(A \cup B) = 1$.

Validity refers to "the extent to which the instrument actually measures what it claims to measure" (Dane, 1990, p. 257; and Sedlack and Stanley, 1992, p. 202) or "the degree of scepticism about the research findings and their meaning" (Robson, 1993, p. 67).

Wallsten and Budescu (1983) argue that validity is decreased by the extent to which the measurement depends systematically on attributes other than that under consideration. *External validity* refers to the extent to which subjectively estimated probabilities correlate with relative frequency counterparts. External validity is established when the correlation of subjectively estimated probabilities with relative frequency counterparts is high (Budescu & Wallsten, 1987). *Construct Validity* refers to the extent of correlation between probability encodings obtained by two or more distinct techniques, and the extent to which the encoded values correctly predicts independent behaviour such as choices. Budescu & Wallsten (1987) report that the correlations between the results of various elicitation methods are generally high, especially among the direct elicitation methods.

Calibration refers to the degree to which the encodings generated by the measurement process correlates with, and is related by an identity transformation to, an independently obtained measurement. Thus, a measure is well calibrated if for all events assigned a probability encoding *p*, the proportion that actually occurs, or is true, is in fact *p* (Wallsten and Budescu, 1987). Calibration is thus an indirect measure of validity.

Generalisability (or "external validity" as used by Campbell & Stanley (1966) and others) addresses the questions: "To what extent and with respect to what properties are they [the measurements] like other sets of measurements one might have taken from a given universe of potential measurements", and, "to what extent and with respect to what properties do they differ from, other sets of measurements one might have taken from a given universe of potential measurements?" (Nachmias & Nachmias, 1981).

The present author contends that despite the objections and criticisms raised about the use of subjective probabilities (and Bayesian analysis for that matter), if the instruments and the means for encoding such probabilities can stand up to the same rules of accuracy and trustworthiness that other method of scientific enquiry and analysis are subjected to, then the knowledge obtained should be as accurate and trustworthy as other forms of scientific knowledge.

3.4 Elicitation Theory and Techniques

Conflicting evidence exist in the literature concerning the accuracy of subjective estimates. Chelsey (1975) suggests, on the basis of works of others such as Kahneman and Tversky (1972), Slovic and Lichtenstein (1972), Barclay & Beach (1972), Wise (1970) and others that although a human is not a Bayesian, the human appears to use decision patterns that exhibit properties similar to statistical rules and reflect a stable underlying inference structure. Winkler (1967) quotes from Suppes (1956) in defence of this view:

"If certain structure axioms are satisfied, any rational man [or woman] acts as if he had an a priori distribution on the states of nature. But what the rational man [or woman] wants is a method for selecting that a priori distribution which best uses his [or her] a priori information"

This view is also supported by the "internal approach" to reconciling incoherent probabilities that assumes "that the subject has, in some sense, a set of internal coherent probabilities that are distorted in the elicitation process. The internal approach is concerned, then, with the attempt to estimate the underlying "true" probabilities using observed assessments" (Lindley, Tversky & Brown, 1979, as quoted in Wallsten & Budescu, 1983).

The works of others such as Fischer (1971) in which he discovered in a probability learning experiment that subjects tended to impose independence where none existed tends to disagree with this view. Wallsten and Budescu (1983) in particular question the appropriateness of thinking of a person's opinion about a set of events as existing within that person in precise, fixed fashion just waiting to be measured. They argue that an individual's opinion is generally vaguely formulated, and upon being asked to evaluate the probability of an outcome, the person searches his/her memory for relevant knowledge and combines it with the information on hand to arrive at his/her best judgement. However, the quality of this judgement is affected by what is retrieved from memory, what aspects of the current information are utilised and the sequential order in which all these parts are integrated into a unified opinion. According to this view, the scale value of an event (e.g. the encoded subjective probability) elicited by a particular technique is a random variable, x, that can be decomposed into a fixed true measure, t, and a random error, e such that:

$$x = t + e$$

The argument here is that whatever the mental state of the person, independent probability encodings would give rise to a distribution of expected values that could be called the true subjective probabilities for the given person, task and situation.

In spite of such conflicting evidence, it is generally accepted that it the function of the elicitation technique to extract and quantify individual judgement about uncertain events, and that the particular technique used will affect the way in which the subjects views the problem at hand and therefore the results obtained.

3.4.1 Approaches to Eliciting subjective estimates

Two general approaches to subjective probability elicitation are reported in the literature, namely, self-elicitation in which the subject elicits his/her own probabilities either alone or within a group setting, and interviewer-elicitation in which a trained interviewer or assessor elicits the probabilities from the individual or group of individuals. The process can be conducted either on an individual basis or at a group level. When using the interviewer approach in particular, a 5-phase process is recommended as follows (Chelsey, 1975; Spetzler & Staël Von Holstein, 1975):

(a) *Motivating* the subject by establishing rapport and investigating the subject's biases.

(b) *Structuring* the uncertain quantity by having it clearly defined.

(c) *Conditioning* the subject by making the subject think fundamentally about his judgement and to avoid any of his cognitive biases.

(d) *Encoding* or quantifying the probability judgements, and

(e) *Verifying* the responses by checking for consistency and seeing if the subject believes his results.

<u>Individual Assessments</u>: In this approach, expert beliefs are elicited from the individual using an assessment technique that allows either self-elicitation or interviewer-elicitation. The beliefs could be expressed in terms of probabilities or dependent variable scale, or in terms of a value or independent variable scale, or a hybrid of the two forms of expression (Chelsey, 1975). Ashton and Ashton (1985) discovered that generally,

aggregates of subjective individual estimates are more accurate than the individuals' estimates that comprised the aggregates and that where it is required to aggregate the individual estimates mathematically, a weighting method or combinatorial rule will need to be applied to the individual estimates. In particular, differential weighting methods that incorporate relative accuracy of the individuals involved produce better aggregate estimates than equal weighting. Furthermore, much of the total gain in forecast accuracy attributable to aggregation can be achieved by combining a small number of individual forecasts. Their findings seem to support the works of others such as Markridakis and Winkler (1983), Winkler and Markridakis (1983) and Lock (1987).

It is also argued that in order to check for consistency or calibration of the individual it is usually desirable to have the subject assess his/her probability more than once and allowing him/her to make his/her preference from among the options known (Chelsey, 1975). Alternatively, one could derive probability distributions for many different quantities and comparing these with the true values of the assessed quantities (Tversky, 1974). It is argued that while this will provide a handle on the expert's skill, to be able to make any corrections one would have to be able to show that the expert consistently over/under estimate, do so by a constant/predicable amount (probably proportion) and that the likelihood of doing so for the particular quantity in question is identical. These seem rather very heroic assumptions.

Group Assessments: A particular elicitation situation may warrant assessment of a subjective probability in a multi-person or organisational context such as commercial or governmental context (Lock, 1987). Three approaches to group assessment can also be distinguished in the literature: the Interacting Group, the Delphi Group and the Nominal Group approaches. In the Interacting Group approach, an initial group discussion on the qualitative property to be measured is followed by a group estimate. In the Delphi Group approach, individuals make independent estimates that are then aggregated by a central group who then provide feedback to the individuals on the group results. The individuals subsequently confirm or revise their estimates until either a group consensus is reached or a satisfactory group variance level is achieved. In the Nominal Group approach, individuals make their initial estimates. This is followed by a group discussion on the subject and estimates, and then the revision/confirmation of the individual estimates to reach a group estimate (Chelsey, 1975 and Lock, 1987). The Delphi approach differs from the nominal group approach in that it separates out the processes of independent opinion generation, structured feedback, evaluation and aggregation of opinions. The works of Chelsey (1975) and Gustafson et al., (1973) in which the nominal group approach proved superior to the Delphi approach would tend to suggest that providing written feedback in the Delphi approach without the clarification of a discussion might lead to a distortion of group results. The Delphi approach is discussed further in chapter 4 of this study.

3.4.2 Encoding Methodology and Response Techniques

Three general elicitation methods can also be distinguished in the literature: the *Probability methods* which require the subjects to specify points on a probability scale while the events remain fixed, the *Value methods* which require the subjects to specify points on a value scale while the probability remain fixed, and the *Probability/Value methods* which ask questions to which the subject must respond on both scales simultaneously. This in essence requires the subject to describe points on a cumulative distribution. The questions posed in any of the elicitation method may require subjects to respond either directly by providing numbers or indirectly by choosing between simple alternatives (Chelsey, 1975; Spetzler & Staël Von Holstein, 1975; Merkhofer, 1987).

Direct Response Techniques include the use of cumulative probability and fractiles in which subjects are asked to assign either the cumulative probability at a given value (e.g. what is the probability that the unknown quantity is less than *X*?), or the value corresponding to a probability (e.g. what is the value of *X* that corresponds to the probability of 15%?). Another technique applies to the *Probability/Value methods* and involves the use of Graphs in which the subject is required to provide joint probability and value assignments by either drawing a density function, a cumulative distribution or state a series of pairs of numbers that correspond to value and probability. Indirect Response Techniques require the subject to choose between simple alternatives or bets. One bet involves the uncertain quantity in the question while the other is a "reference lottery" consisting of some physical devise (such as a probability wheel) or conceptual situation where the probabilities are easily understood and computed, such as fixed probability events like tossing ten "heads" in a row with an unbiased coin. (Merkhofer, 1987).

Invariably, the elicitation approach and encoding methodology used would be a function of its cost, the subjects and the form of their knowledge, and the practicality and applicability of the approach to the subject matter of the elicitation.

3.5 Summary

The aim of this chapter was to present a critical review of the literature on subjective probability and techniques for eliciting subject expert opinions as input variables for the analysis of risks and uncertainties. Starting with a brie discussion on the development of probability theory and the nature of probability, the chapter went on to discuss subjective probability, its uses in Bayesian analysis of uncertainties and how such analyses could be applied to contractual risks, which by their nature, are very similar to the types of uncertainties for which Bayesian analysis using subjective probabilities are employed. The chapter concluded with a discussion of elicitation theory and the processes and techniques for encoding subjective probability estimates. The aim of this section of the chapter was lay further foundation for an understanding of the elicitation model adopted for this study for capturing and transforming subjective expert estimates of probabilities into representative probability distributions than can be used as input variables for rigorous probability analysis of contractual risks.

Chapter 4 discusses the development of the research approach adopted for this study and the rationale for such a design. In addition to ensuring validity as a scientific study, the chapter aims at demonstrating how appropriate data for the rigorous, Bayesian analysis of contractual risk can be easily obtained and applied. The first section of the chapter completes the literature for this study by looking at some of the philosophical and methodological issues within the broad fields of social research that have a significant impact the current research. The rest of the chapter then draws on the reviews presented in chapters 1 through 4 and the current author's prior knowledge to develop the research methodology used in the present research.

CHAPTER 4

RESEARCH METHODOLOGY

4.0 Introduction

The previous chapters discussed the haphazard manner in which contractual risks tend to be analysed and managed in the construction industry. Chapters 2 and 3 presented a review of the literature on risk management and discussed how elicitation and subjective probability analysis techniques are being successfully applied in other industries to risks that are similar in nature to contractual risks. The chapters discussed the potential of applying similar approaches to risks in construction. The major stumbling blocks to applying such approaches to contractual risk, which was also discussed, remain the cost involved and the unavailability of relative frequency data on the risks associated with construction contracts. Any system aimed at achieving an acceptable standard of rigour in contractual risk analysis would therefore need to address the issues of cost and data availability.

This chapter discusses the development of the research approach adopted for this study and the rational for such a design. In addition to ensuring validity as a scientific study, the research design aims at demonstrating how appropriate data for the rigorous analysis contractual risk can be easily obtained and at no significant extra cost. The chapter consists of seven parts. The first part reviews literature that address some of the philosophical and methodological issues within the broad fields of social research that have a significant impact the current research. The purpose of this review is to provide a better understanding of the methodology designed for the present research and the rational for choosing such a design. The rest of the chapter discusses the research methodology used in the present research, and is organised as follows:

(a) The Philosophy and Methodology of the Present Research (section 4.2)
(b) Research Design (section 4.3)
(c) Research Sampling (section 4.4)
(d) Data Collection Strategy (section 4.5)
(e) Data Analysis (section 4.6) and
(f) Limitations of the Research Methodology (section 4.7).

4.1 Defining Social Research

Just like the concept of risk, "research" caries probably as many definitions as the groups of people who engage in it. Nachmais and Nachmais (1981) for example defined research as "the overall scheme of scientific activities in which scientists engage in order to produce new knowledge" (page 22). However, not all research is done by scientists argues Kerlinger (1973), who defines research as "systematic, controlled, empirical and critical investigation of hypothetical propositions about presumed relationships among natural phenomena" (page 11). While research is best done in a systematic and controlled manner, not all research is conducted in this manner. Dane (1990) contends that even poor research, is still research (page 4) and defines research broadly as "a critical process for asking and attempting to answer questions about the world".

Within this broad definition, the ultimate goal of social science is "to produce an accumulating body of reliable knowledge that would enable us to explain, predict, and understand empirical phenomena that interest us, ... [and that] could be put to use to ameliorate the human condition" (Nachmias and Nachmias, 1981, p.9). These explanations, whether deductive, universal generalisations, or inductive, probabilistic generalisations, are sought by pursuing a systematic and empirical analysis of those antecedent factors responsible for the occurrence of a phenomena in a given situation.

4.1.1 Philosophical issues of Social Research

To achieve the objectives of a social enquiry, social research therefore addresses two essential and inter-related philosophical questions regarding claims about knowledge, and the ways in which one knows that provides justification for claims about knowledge. On the one hand then is the ontological question of what kinds of things exist in human society. On other hand we have the epistemological issue of the character or nature of the knowledge we have about human society or what should be admissible as facts (Hughes, 1990). In addressing these issues, the social researcher designs "an argument which shows how a set of conclusions follow, set by step, from some agreed-upon premises. If the premises are agreed and the steps consistently and rigorously followed, then the conclusions must follow as a matter of logical argument, no matter how outrageous they may seem commonsensically" (Hughes, 1990). However, social research is conducted within the context of a social science discipline. It thus involves the use of skills and tools (or methodology) appropriate for that particular discipline. The appropriateness of methodology for finding and ascertaining knowledge raises the issues of the paradigms or theories of knowledge on which social research and methodologies are based.

4.1.2 Positivist and Interpretive (Qualitative) Paradigms

The relationship between research data and theories of knowledge has been a subject of long-standing and heated debate among philosophers and social researchers. Two main paradigms or traditions can be distinguished in this historical battle over the theories of knowledge. One tradition is the philosophy of science typically represented by Auguste Compte and Jim Stuart Mill (Bynner & Stribley, 1978). It is generally called positivism, but goes by other names such as empiricism, behaviourism, or naturalism. The second paradigm, which was a reaction against positivism, is often referred to as the interpretive or qualitative paradigm often associated with Droysen, Dilthey, Simmel and Max Weber. The "hermeneutic" philosophy associated with Dilthey and the "phenomenological" paradigms are other names by which the qualitative paradigm is sometimes go.

One of the essential tenets of positivism is that reality consists of what is available to the senses (Hughes, 1990). According to this tenet, the world exists externally independent of its actors. Its attributes should therefore be measured using "hard or brute data" collected in a controlled, reliable and systematic manner and verified objectively, rather than inferred subjectively through sensation, judgement, reflection, interpretation, intuition or some other subjective mental operation. Positivist research methodologies thus emphasise objective observation and measurement which typically involve the "hypothesis testing" approach to scientific enquiry in which a theory or hypothesis about the nature of some aspect of the world is postulated. Data on the attributes of this aspect of the world are then sought using quantitative methods to either prove or disprove the postulated hypothesis. The approach may heavily rely on mathematical and statistical procedures for analysing these data using probabilistic and inferential assumptions in order to provide "causal" explanations of phenomena using the hypothetically assumed general laws of nature (Onwuegbuzie, 2002).

Another tenet of positivism is "methodological monism" or the idea of the unity of scientific method by which it claims that both the natural and human sciences share common logical and methodological foundations. Thus, although the subject matters of the two sciences require different methods of investigation, the difference is only pragmatic and not a logical or principled difference. Positivism therefore claims the existence of a fundamental distinction between fact (with which science deals) and value. Attempts to account for facts in terms of value or intentions, goals or purposes are considered "unscientific".

The anti-positivist (qualitative) philosophy of science challenges the central tenets of positivism and advocates an alternate methodology for the social sciences. The "Interpretavist" emphasises the contrast between those sciences that aim at generalisations about reproducible and predictable phenomena, and those which want to grasp the individual and unique features of their objects. The German historian-philosopher Droysen for example, argued that while the aim of the natural sciences was to provide "explanation" or "*erklären*", the aim of the social sciences was to gain "understanding" or "*verstehen*" of the phenomena which falls within its domain (Bynner & Stribley, 1978). Dilthey also noted that whereas the natural sciences dealt with inanimate objects that often exist independently of human beings, society as a product of the human mind was subjective, emotive as well as intellectual (Hughes, 1990). Dilthey argued that due to this fundamental difference in subject matter, the causal, mechanistic and measurement oriented methods of natural science inquiry were inappropriate for social inquiry since human consciousness was not determined by natural forces.

Proponents of the interpretive paradigm argue that the world is known through the eyes of its actors, and recognise symbolism and language as characteristics of humanity. Interpretavists see social inquiry as process oriented and emphasise subjectivity, meaning, motives, understanding, discovery and exploration. It is "hypothesis generating" approach to research (Robson, 1996). Data for the study of aspect of the world are sought using qualitative methods and naturalistic, uncontrolled measurements such as interviews, participant observations, conversational analysis, etc. In attempting to reconstruct the subjective experience of social actors, two major methodological principles (advanced by Weber) guide qualitative enquiry. The first is the principle of value neutrality. This holds that scientists cannot pass judgements or have anything to say about conflicting values as to which is to be preferred, but can only review the likely outcomes of various value alternatives (Hughes, 1990). The second principle is the concept of ideal type. This principle, which seeks to transform "understanding" into the construction of rational models, holds that all irrational and emotive aspects of human behaviour are to be seen as deviations from a conceptually pure form of rational action (ideal type). The ideal type is thus both clear and free from ambiguity.

Although *purists* among the positivists and the interpretavists see their philosophies as incompatible and advocate mono-method studies, *situationalists* argue that certain methods are more appropriate for specific situations. The 1960s saw the growth of the pragmatic school of thought, which assert that research is influenced by theory and hypothesis and also by observations, facts and evidence. *Pragmatists* therefore advocate mixed-method studies (combining quantitative and qualitative methods within different stages of the research process) and apply both inductive and deductive logic, formal and informal language and choose explanations that best produced desired outcomes (Onwuegbuzie, 2002). Glaser and Stauss (1967) contend that the task of the researcher is to develop theory through a "comparative method" which studies the same event or process in different settings or situations. Such an integrated approach enables the use of qualitative date to generate and verify theory. Denzin (1978, p.291) called this "combination of methodologies in the study of the same phenomena" as triangulation.

4.2 The Philosophy and Methodology of the Present Research

As discussed in chapter 1, the main focus of the research is to investigate the use of elicitation and probability analysis techniques for quantifying expert opinions as subjective probabilities for use as input variables in contractual risks analysis in construction. In doing so, the research seeks to address the issue of the nature of contractual risks and how subjective expert opinions and perceptions about these risks influence the risk management effort and hence project management.

To serve as a recap, the main objectives of the study are:

(a) To conduct a review and survey aimed at establishing the types and current usage of risk management techniques in the construction industry;

(b) To investigate risk perception in the construction industry and its impact on project performance (price);

(c) To develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception, and provides these opinions as an input variable to the systematic and effective analysis of contractual risks.

Robson (1996) argues that the general principle in research design is the employment of research strategy or strategies and methods that are appropriate for the issues to be resolved. Although the different objectives of the research are achieved in the same study, the nature of the tasks involved and the issues to be resolved in achieving each objective are quite different. The research therefore adopted the pragmatic philosophy of mixed-method design and triangulation and employed research instruments that were considered most appropriate for achieving each objective within the same study. The task involved in achieving each objective and the research philosophy and methodology employed are discussed below.

4.2.1 Establishing the types and current usage of risk management techniques

The purpose of this part of the study was to evaluate the appropriateness of the methods currently used for identifying, analysing and planning responses to contractual risks. In essence, this part of the study is to test the following assertions:

That although applications and use of systematic and rigorous probabilistic methods to risks in other industries can only point to the enormous potential that such methods present to the construction industry,

(a) there is very little application, if any, of systematic and rigorous probabilistic methods to contractual risk in construction;
(b) analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques.

These assertions are in essence, theoretical constructs that needed testing with real life responses. This part of the research therefore adopted a positivist approach, using a standardised questionnaire as the main method of primary data collection and analysis. Major conclusions of this part of the research are therefore empirically based, induced from the analysis of the data collected. The rational for adopting this approach are fully explained in section 4.3.

4.2.2 Risk perception and its impact on project performance (price)

This part of the research was aimed at studying the nature of risk perception, the impact of socio-culture on risk perception and the influence of risk perception on estimates about risk. The purpose of this part of the study was to demonstrate

(a) that differences in individual perceptions about risks will result in differences in their estimates about the same risks
(b) that differing socio-cultural backgrounds of risk experts will lead to significant differences in their estimates the same risks.

In studying the nature of perceived risk and understanding how it is influenced by socio-cultural settings, research in this area relied on both existing published work and primary data collected from a series of surveys and desk-studies, to inform the discussion on risk perception in construction and the impact of risk perception on project performance. Project performance in construction is often measured using price/cost as a major yardstick. The logic here is that since estimates for risks form such a significant part of project costs (Cullivan, 1981), any significant difference in risk estimates implies a significant difference in project price and hence project performance. Risk perception in the context of this study refers to the view, opinion or belief held by a party about the likelihood of occurrence and/or the impact of a risk.

In dealing with perceptions of different parties, it is important that a uniform definition of the risk be provided to ensure that the different views expressed refer to the same risk. Part of the study in therefore required clearly defining a risk and obtaining statements of beliefs in from experts regarding the defined risk. Obtaining "quantified" beliefs or judgements required an approach that is different from a simple survey questionnaire. It was considered more appropriate to adapt the vignette and Delphi interviewing techniques into a hybrid research design for eliciting quantified expert opinions about the occurrence and impact of the defined risk.

In the traditional vignette technique, short stories about hypothetical characters in specified circumstances are given, and the interviewee is invited to respond (Finch, 1987). Traditional Delphi techniques involve getting together a group of persons with interest in the focus of the research and presenting them with some background to the issue(s) at stake. Each person is subsequently invited to independently generate responses on the issue(s) at stake, and questions/responses raised are discussed the with a view to seeking resolution or consensus through voting, ranking etc. (Robson, 1993). The revised Delphi methodology as used in macro-environmental analysis was adopted for this study. The stages involved in the Delphi approach is summarised from Parenté & Anderson-Parenté (1987) and De Wit & Meyer (1994) as follows:

(i) Exploring the subject matter and defining the Delphi goal(s)
(ii) Identifying recognised experts in the subject matter;
(iii) Soliciting the co-operation and participation of the experts;
(iv) Providing experts with an initial position paper on the status of the issue;
(v) Eliciting of individual expert opinions on the subject matter or issue;
(vi) Aggregating the individual expert opinions to form a group opinion
(vii) Providing feedback and clarification to experts on the group results and eliciting revised opinions;
(viii) Reaching a final group consensus with acceptable level of variability.

The details of the research design and the rational for adopting this approach are fully explained in section 4.3.

4.2.3 Developing a model for eliciting quantified opinions about contractual risks

The similarity between contractual risks and certain economic risks for which subjective probabilities are used for their analysis was established in the previous chapters. The elicitation techniques used in obtaining quantified opinions from experts for use in economic analysis were also discussed in chapter 3. The tasks left to be done here involved testing the applicability of the reviewed elicitation techniques and processes to contractual risks. This required

(a) applying similar techniques and processes used for eliciting quantified expert opinions for economic risks analysis, to comparable contractual risk to establish suitability for generating similar estimates from construction experts.

(b) developing the quantified opinions into probability estimates that can be used as input variables for the subjective probability analysis of contractual risks.

This part of the study essentially involved designing and testing of an effective approach to eliciting expert opinions about contractual risks within different socio-cultural settings. The design of the elicitation approach was heavily informed by the review of the literature discussed in chapter 3. This design revolved around the vignette and Delphi interviewing techniques described in section 4.2.2. Pre-test and pilot surveys were used to test the initial designs of the approach. The final design was then used in the main study. The detailed explanation of the methodology is discussed in section 4.3 below.

4.3 Research Design

The underlying rationale for the research design is presented schematically in Figure 4.1. The two countries selected for the study were the United Kingdom and Ghana that present two different socio-cultures and development economies. Ghana on the one hand typifies a liberalised and emerging economy with its own unique social and cultural systems that impact on perceptions regarding risk. Thus, although hard data are used in all forms of construction estimating and management, the environment in which contractual risk analysis and management decisions are made affected by factors that are unique to Ghana. The United Kingdom on the other hand typifies the developed and established economy of the western world, with a socio-culture that often stands in sharp contrast to the Ghanaian socio-culture. In terms of research analysis, a study involving these two countries presents a number of research benefits and issues.

Firstly, analysis of data generated from samples of risk experts from each country is to be generalised for the entire country (statistical generalisations). Secondly, as a typical liberalised and emerging economy, the generalised conclusions from the Ghana-based data are then applied to other emerging economies - analytical generalisation (Yin, 1994). Results from the UK data are treated in a similar manner. Thirdly, a comparison between the results from the two countries will shed some light on how the different practices adopted by the construction industries within the different socio-cultural and economic settings affect project pricing and hence performance. Fourthly and most importantly, the successful use in both countries of the elicitation model developed by the research gives further credence to the reliability, validity and effectiveness of the model in generating quantified expert opinions across cultures or economies. The results will also thus be immediately relevant to contractors from a developed economy (UK) seeking to enter a developing economy (Ghana).

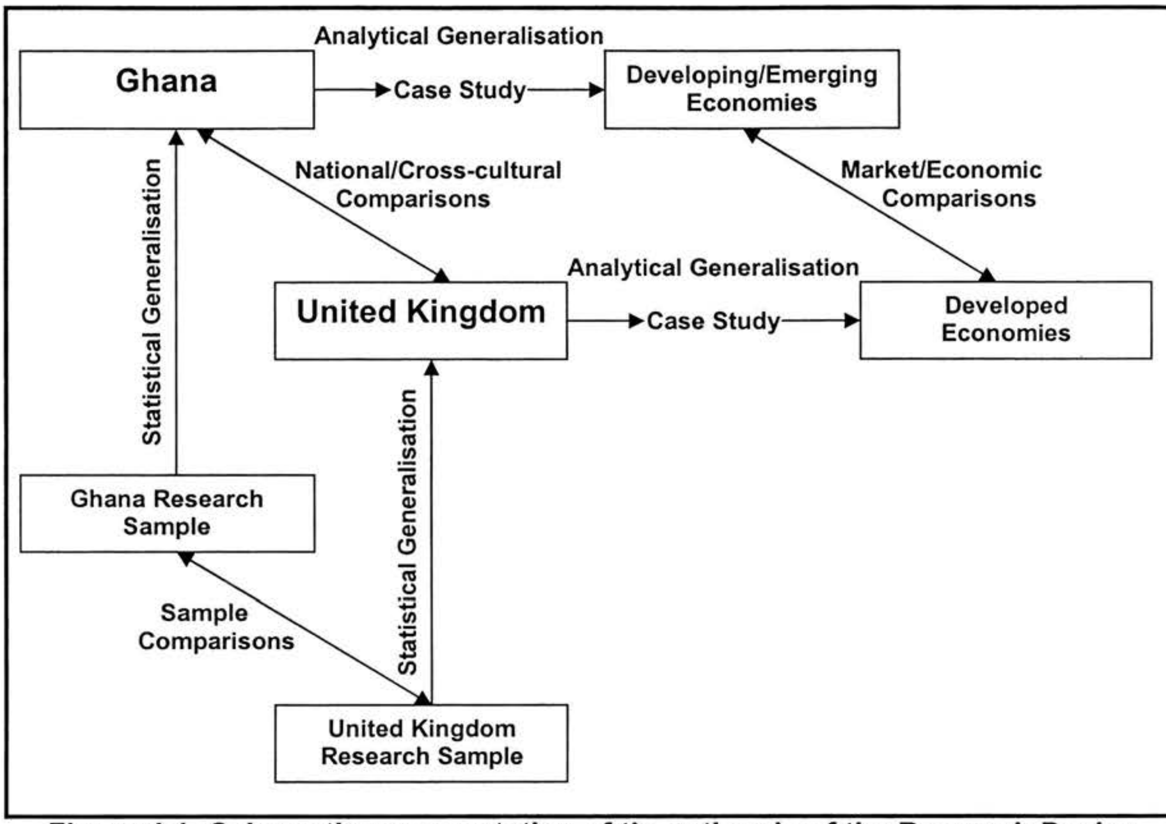

Figure 4.1: Schematic representation of the rationale of the Research Design

To achieve the objectives of the research, the research was conducted in three phases consisting of pre-test, pilot and main studies. Primary data for the research were collected from questionnaires and interviews during the pilot and main studies.

(a) The Pre-Test

The research relied on the literature, previous research and other researchers and experts in providing an initial structure of the research questions and instruments for the pilot study conducted in the UK, and the main studies conducted in the UK and Ghana. While the information gleaned from the literature is critical, it is extremely difficult to develop a sound project plan and programme for a research project of the kind undertaken by this study without an adequate knowledge of its subject matter, the population of respondents, how meaningful the survey questions will be to the respondents, how respondents will react to the research questions, what kinds of answers they are likely to give, whether the surveys are worth asking at all or whether answers from respondents will help resolve the research questions! (Moser & Karlton, 1979; Dane, 1990). The purpose of the Pre-Test survey, although limited in scope, was thus to systematically try out all the key measures and features of the survey instruments on small samples of the survey population and other researchers and experts in the subject matter of the research, and to use the findings of the pre-test to fine-tune the survey instruments for the pilot and main surveys.

Among other things, the pre-test sought in particular to test the issues of the research raised in sections 4 and 5 of the Pilot Survey Questionnaire (appendix 2), and the appropriateness of the elicitation approach that was being developed. The key risk for which expert opinions were sought in the pre-test was the risk of adverse ground conditions in construction contracts. It was decided to investigate this project risk parameter for a number of reasons. Firstly, by virtue of the facts that construction projects are landed capital projects and that ground conditions can vary significantly from one location to the other even on the same project site, the risk of adverse ground conditions is one that will be faced by every new construction project even for projects with similar designs. The results of the study would thus be of immediate benefit to the construction industry and applicable internationally. The review of the literature (e.g. Norgrove & Attewell, 1984; Littlejohn *et. al.*, 1994) and the personal experience of the author confirm the fact that the risk of adverse ground conditions is one of the key project risks that greatly affect the performance of the project in terms of escalating costs and late project completions. Another feature tested was the presentational format of the survey instruments. Given the specialist and difficult nature of the key questions sought, it was considered necessary convey to the respondents the importance of the research and to motivate respondents to respond by also adopting a layout design that was "appealing" to the respondent and demonstrated the considerable effort put in by the researcher into the design of the instruments.

The first preliminary design of the Pilot Survey Questionnaire (appendix 2), was tested on a group of three construction researchers from Napier University. Feedback from these tests was combined with feedback from the academic reviews of the instruments from two of the academic staff of the Department of Business Studies, The University of Edinburgh. The revised design was then tested among three UK professionals who were sampled from the list of pre-qualified survey participants obtained using the Pre-qualification survey instrument (Appendix 1). The test involved mailing the participants the instruments and obtaining responses and comments over the telephone. Results from the pre-tests led to the finalisation of the Pilot Survey Questionnaire (appendix 2).

(b) The Pilot Survey

Like the pre-test, the pilot survey also tests the measures andfeatures of the main study. Unlike the pre-test however, the pilot survey is a small-scale replica of the main survey and therefore involves a test run of the entire research procedure (Moser & Karlton, 1979; Dane, 1990). The purposes of the pilot survey conducted for this study were as follows:

(i) To collect primary data on the respondents and the types and current usage of risk management techniques in the construction industry. Data from this part of the survey were to be analysed to address the objective of the research discussed in section 4.2.1. This part of the instrument therefore adopted a standardised questionnaire for data collection (see Section 3 of Appendix 2). Although it would have been ideal to have conducted this part of the research as a separate survey, it was considered that the data sought by this part of the research were of such straight-forward nature and yet so recognisably different from the rest of the questions in the survey instrument that it was possible to include them in the Pilot Survey as a separate section without interfering or detracting from the other key sections of the survey. Placing these relatively simple and straight-forward set of questions as the first key section would also encourage participant response by providing them with the first impression that the instrument was relatively simple and easy to complete. This approach would also reduce "respondent fatigue" by minimising the number of separate times information is requested from the same respondent regarding the same project. Further, it was considered economically prudent to do so in view of the financial resource constraints on the project.

(ii) To validate the adequacy of the sampling design adopted for the research (see section 4.4). Although the experts prequalification survey identified appropriate experts for involvement in the research, it was important, in view of the lack of control by the researcher over who actually completes a mail questionnaire, to the reliability of the research to demonstrate that the actual survey respondents would still be people who would fit the "expert" criteria on which participants were selected.

(iii) To investigate the adequacy of variability in the survey respondents (professional groupings and industrial sectors) inform the selection of the final sample size and to support the generalisability of the research results.

(iv) To obtain experts' views on what they consider to be the major risks they face in international contracts. These views would guide the selection of the risk parameters for which expert opinions will be sought in the main surveys.

(v) To investigate the suitabilities of the elicitation approaches used in the pilot survey.

(vi) To test the adequacy of the questionnaire. Although some of the key measures and features of the instrument would have been tested during the pre-test and feedback obtained from other researchers, the ease with which respondents answer questions, the efficiency of the layout and the clarity and efficiency of the instructions and questions would provide vital guidance for the design of the main survey instruments.

(vii) To test the efficacy of elicitation model being developed by the research. One of the key objectives of the research was the development of an elicitation model for eliciting quantified opinions about risks for use as input variables in the probabilistic analysis of contract risks. Thus a key objective in the pilot study was to analyse the efficiency and efficacy of each aspect of the pilot survey process in order to inform the development of the final model.

The pilot study was conducted between March and June 1997. Due to the financial constraints imposed on the research, the pilot survey was restricted to construction experts in the UK. Data from Ghana on the types and usage of risk management techniques in the Ghanaian construction industry was therefore not obtained using the standardised questionnaire described in (i) above. Instead, the data was collected as part of the main Ghana survey details of which are described in section (c) below.

Following the pilot study, follow up interviews were conducted with selected construction experts from both the UK and Ghana. The follow-up interviews were scheduled in December 1997 and conducted between January and February 1998. These interviews were aimed at obtaining further information on the main factors that companies involved in international contract bidding consider in their risk management efforts and processes. Results from these interviews were thus to further inform the final design of the research instruments for the pilot and main studies and to further enhance their reliability and validity. The reliability of an instrument refers to the extent to which it produces consistent results when a characteristic or situation is measured repeatedly using the instrument. Validity refers to the extent to which a measure actually corresponds with what the researcher is trying to measure.

The procedure followed in the pilot survey is described in section 5.3.1, and the fnal survey instruments developed as following the study are included in appendices 3 to 6.

(c) The Main Surveys

The reasons for conducting these two surveys were explained earlier in this section. The purpose of the main surveys was three-fold:

(i) To collect primary data on risk perception among construction experts and the impact of socio-cultural differences among experts on their perceptions of the same risks. Data from this part of the survey were to be analysed to address, in part, the objective of the research discussed in section 4.2.2

(ii) To elicit estimates from the construction experts within both a socio-culturally homogeneous and heterogeneous settings, regarding the likelihood and impact of specified project risk parameters within an international project context. Data from this part of the survey were to be analysed to complete the discussion of the research objective discussed in section 4.2.2, and address the research objective discussed in section 4.2.3(b)

(iii) To reach a group consensus with acceptable level of variability among the experts regarding their estimates. After the analysis of responses from the experts on both individual and group basis, respondents were to be subsequently provided with telephone feedback on their estimates and how they compared with the group aggregates. They were then given the opportunity to evaluate their own estimates in the light of the group results by maintaining their original estimates, adjusting them or accepting the group aggregates as being more representative of the risk parameter in question.

(iv) To validate the elicitation model tested through the pilot survey (see section 4.3(b)(vii)) in both socio-culturally homogeneous and heterogeneous settings. The achievement of this purpose was necessary for the accomplishment of the third objective of the research discussed in section 4.2.3

The main surveys consisted of two parts – a UK Survey and a Ghana Survey. Each survey, which consisted of the use of both self completion questionnaires and interviews, was to measure perceptions and expert estimates about risks within a socio-culturally homogeneous setting. By comparing the individual estimates of experts within the same homogeneous setting about the same risks, the research would have demonstrated part (a) of the research assertions on risk perception (see section 4.2.2). The two sets of data also represent perceptions and expert estimates from two socio-culturally heterogeneous settings. Thus, by comparing the aggregate estimates or mean "belief functions" of experts from the UK and Ghana (representing two different cultures), the research would have demonstrated part (b) of the research assertions on risk perception (see section 4.2.2). The argument here is that although experts within the same culture will give different estimates for the same risks within the same culture based on their perceptions of the risks within that culture, the mean of their estimates about similar risks in a different culture will reflect their "collective" perception of the risks within the new culture that is different from their own (Li & Karakowsky, 2001). This is evident in how contractors from the UK generally and consistently price the risks associated with overseas projects higher than their local counterparts (Cullivan, 1981).

The analyses of the results and feedback from the pilot survey lead to refinements in the pilot survey instrument and the production two separate survey instruments for the main surveys. The first instrument, the Risk Perception Survey Questionnaires (appendices 3 and 5), aimed at measuring risk perception among construction experts. This study on risk perception is similar to the works of others such as Slovic *et al.* (1980) and the objective was to test the underlying research assertion (see section 4.2.2(a)) that differences in individual perceptions about risks would result in differences in their estimates about the same risks. The approach was to use the actual data about the occurrences and severity of the specified construction risks (accidents) to calibrate the estimates of the experts about the same risks. Accident fatality was used as a measure of risk severity since there is a direct relationship between fatality of an accident and its impact on the project. For example, an accident that result in the death of a worker will have a greater impact on the project (e.g. temporary project suspension, financial compensation to the bereaved family, etc) than one that results in a minor injury to a worker (e.g. on-site treatment at the Site Office, day-off from the site, etc). This calibration coupled with the analyses of the personal information and risk experience of the experts would lead to an understanding of the nature of risk perception in construction and also demonstrate part (a) of the underlying research assertion that differences in individual perceptions about risks would result in differences in their estimates about the same risks. The key risks investigated were to be identified through a desk-study of construction accidents, injuries and incident investigation records and statistics of the Health & Safety Executive of the United Kingdom and its counterpart in Ghana. The set of nine risks (accidents) that formed the basis for are discussed in section 4.3.3(b) below. "Actual" data on the risks was to be obtained through the same desk-study and the purpose of the Risk Perception Survey Questionnaire was to generate estimates of the experts about the risks identified through the desk-study.

The second instrument, the Risk Likelihood and Impact Survey Questionnaires (appendices 4 and 6), aimed at eliciting expert estimates of the likelihood and impact of risk parameters that had been identified during the pilot survey as the four major risks faced in international construction (see section 4.3(b)(iv). The approach is similar to the one used in pilot survey and the design of the survey instrument is discussed in detail in section 4.3.3(c) below. The procedure followed in the main surveys is also similar to that followed in the pilot survey and described in section 5.3.1.

The Ghana Survey

As stated above, data from Ghana on the types and usage of risk management techniques in the Ghana was not obtained using the standardised questionnaire used in the pilot survey. Instead, section 2 of the pilot survey questionnaire was used a guide for a series of semi-structured interviews (part of the first face-to-face interviews with the experts) that were held during the main Ghana survey conducted between June and

September 1998. At each interview, key areas for discussion were highlighted and groups of open-ended questions within these areas asked. Respondents were given the freedom to talk generally and in as much detail as they could in responding to these questions. The key groups of questions asked during the interview are summarised in section 4.3.2(a).

Also, although a desk-study and analysis of construction accidents, injuries and incident investigation records and statistics described above was attempted in Ghana in order to provide a cross-cultural analysis of risk perception in construction, construction accident and incident recording systems in Ghana were found to be almost non-existent. Three months of consistent efforts confirmed that no meaningful records of accidents existed at either corporate or national levels. Furthermore, most of the Ghana respondents had difficulty completing the Risk Perception Survey questionnaires. The survey using the Risk Perception Survey questionnaires could therefore not be completed in Ghana.

The use of the Risk Likelihood and Impact Survey Questionnaires were however successful in the Ghana survey and the results are analysed and discussed in chapter 5.

The UK Survey

The UK survey was conducted during October and November 1998. Having gathered the relevant data on the types and current usage of risk management techniques in the UK construction industry through the pilot survey, the main UK survey focused on gathering research data using the Risk Perception and the Likelihood and Impact Survey questionnaires described above. Both surveys were successfully completed and the results are also analysed and discussed in chapter 5.

4.1.1 Questionnaire Design

The objectives of the questionnaires were three-fold.

(i) To profile the characteristics of the survey respondents and of sub-groups within the respondent population. This information would be useful first of all in demonstrating that the actual survey respondents fitted the "expert" criteria on which participants were selected, and thereby attesting to the reliability of the research.

(ii) To collect primary data on the respondents and the types and current usage of risk management techniques in the construction industry. Data from this part of the survey were to be analysed to address the objective of the research discussed in section 4.2.1. Structured standardised questionnaires were adopted for accomplishing this objective which was one of the objectives of the UK-based pilot study. The reasons for making this part of the pilot survey were discussed earlier in section 4.3(b). The questionnaires used here comprised mainly of a set of pre-prepared questions each having a domain or a set of answers from which respondents were to choose. The option was also provided in each domain of answers for respondents to indicate their responses if their answer was not included in the list provided.

(iii) To collect primary data on risk perception among construction experts within both a socio-culturally homogeneous and heterogeneous settings. Data from this part of the survey were to be analysed to address, in part, the objective of the research discussed in section 4.2.2

(iv) To elicit quantified opinions from the construction experts within both a socio-culturally homogeneous and heterogeneous settings, regarding the likelihood and impact of specified project risk parameters within an international project. Data from this part of the survey were to be analysed to complete the discussion of the research objective discussed in section 4.2.2, and address the research objective discussed in section 4.2.3(b).

The use of the questionnaire approach in the survey was considered prudent for a number of reasons. In addition to the benefit of being able to test the research constructs with real life responses, the questionnaire approach was considered beneficial due to its high efficiency in terms of research cost, time and effort. Several copies of the carefully constructed questionnaire could be mailed out to the sampled respondents, filled and returned in about the same time that it would take to schedule and complete a single interview. The time needed to code and analyse responses from the questionnaires would be similarly short. Furthermore, as Nachmias and Nachmias (1981) point out, self-completing questionnaires do not require trained staff of interviewers; all it needs is the cost of planning, sampling, duplicating or printing, mailing and providing stamped self-addressed envelopes for their return. This lower cost was considered particularly important since the sample was widely spread geographically.

Another benefit that was to be gained from using questionnaires was that of reduction in biasing errors that result from the personal interviewer characteristics and from variability in interviewer-skill (Nachmias and Nachmias, 1981). Cicourel (1964) argues that in order to achieve reduction in biasing errors, the questionnaire "must incorporate the language and cultural meanings inherent in the respondent's perspective in daily life, the researcher's perspective and the rules for translating these meanings into basic and substantive theory". The questions and response domains in the present research used language that is part of the training and the regular professional practice of both the researcher and respondents. The potential for diminished gains in reducing biasing errors was therefore removed. Self-completion questionnaires were also considered preferable since the questions demanded a considered (rather than an immediate) answer, and the questionnaire encouraged respondents to consult other people if necessary, in order to firm up their opinions. Other advantages of this approach included the reliability of measurements and its amenability to making statistical inferences and generalisations from data collected. Restricted domain of responses ensures that consistent responses are obtained over all respondents. In addition, since responses have to lie in given domains, applying formal statistical techniques in the analysis is a relatively straightforward process.

There are however, some drawbacks in the use of self-completion questionnaires. One such disadvantage results from the constraints imposed by the researcher on responses by the undue emphasis placed on the researcher's ability to predict á priori, the appropriate questions to ask, and their response domains. However, significant experience and knowledge of the field under investigation as well as extensive literature review by the researcher should minimise this constraint. Due to a numberof reasons, it was considered that constraints imposed by the researcher would be minimal if at all present. Firstly, the researcher had significant knowledge and experience of the field under investigation. Secondly, the questionnaire design was informed by both academic training and extensive review of the literature. Lastly, consultations were made with other researchers and experts to ascertain the appropriateness of the questions asked and the completeness of the response domain for each question.

Robson (1993) also argues that the data obtained by this means is necessarily superficial, with little or no check on the honesty or seriousness of the responses. In most cases, responses have to be squeezed into predetermined boxes that may or may not be appropriate, and the respondent has no assistance in understanding the questions asked. This calls for the use of questions that are straight forward and unambiguous enough to be comprehended solely with the help of printed instructions and definitions. What is often considered as an even more serious drawback as far as it relates to questions of reliability is the almost complete lack of control over who actually fills out the questionnaire. The argument is that since researchers have no control over the respondent's environment, they cannot be sure that the right person completes the questionnaire. An individual other than the intended respondent may complete it. This is very common particularly in questionnaires that seek to obtain data from key senior personnel within organisations. The potential for these drawbacks was removed from the present research through the data collection strategy. This strategy included providing either telephone or face-to-face discussions between the researcher and respondent during which discussion any needed clarifications were provided on the questions and answer domains. Furthermore, respondents in this study were experts who had also expressed a personal interest in, and willingness to be involved in the research prior to their receipt of the questionnaires.

Perhaps the most serious problem with self-completion questionnaires is that they often fail to obtain an adequate response rate. The typical response rate for a personal interview could be about 95%, whereas that for a mail survey of the same nature could be between 20% and 40%. As Nachmias and Nachmias (1981) points out, this often leaves the researcher with the problem of how to estimate the effect the non-respondents, who are usually quite different from those who answered the questionnaire, may have on their findings. The response rate of the study was no exception to this general observation. Based on some of the comments made by some of the non-respondents, this was attributed to either lack of time or adequate relevant experience by the non-respondents.

4.1.2 Questionnaire Content and Format

Four distinct types of questions are distinguished in the survey literature: *behaviour*, *beliefs, attitudes* and *attributes* (de Vaus, 1996; Foddy, 1993). "Behaviour" questions seek to identify what people *do* and are useful in providing a map of what groups of the respondent population perform the activities that are of interest to the research. These types of questions therefore also help in locating those factors that facilitate or hinder the activities that are of interest to the research. Questions about whether the respondents perform certain risk management activities on construction projects are an example of *behaviour* questions. The focus of "Beliefs" questions is to identify what people believe is true or false rather than on the accuracy of their beliefs. Eliciting expert estimates about the occurrence of certain risks in construction projects or the percentage of projects that are likely to encounter accidents on construction sites are thus *belief* questions. Whereas "beliefs" questions seek to identify what people believe is true, "attitudes" questions seek to establish what people think is desirable and might involve, for example, asking construction experts about what whether or not they feel contractors should be responsible for the risk of adverse ground conditions in construction contracts is an attitudinal question. "Attribute" questions seek to obtain information about the respondents' characteristics and would include questions about occupation, years of construction experience, nature of business, etc.

The objectives of the present research and the nature of the information required necessitated a mix of *behaviour, beliefs* and *attribute* questions in the design of the survey instruments. *Attribute* questions are often the easiest and least threatening to the respondent as they seek information that are often readily available to the respondent and requires little thought on the part the respondent. These questions therefore naturally formed the first section of all three types of questionnaires used in the research. Where such questions are warranted in a separate section in the instrument that dealt with a separate topic of the survey, they were also asked first (see for example questions 1 and 2 of section 4 of the Pilot Survey questionnaire). The use of the other types of questions in the surveys is described below.

(a) Pilot Survey Questionnaire

The data required to achieve the objectives of the pilot survey necessitated the use of *behaviour, beliefs* and *attribute* questions. The objectives also required asking groups of questions relating to the following:

(i) the expertise of the respondent
(ii) the risk management behaviour of the respondent
(iii) attributes of some of the projects handled by the respondent
(iv) attributes of soil types encountered by the respondents on projects
(v) respondent beliefs about the occurrence of adverse ground conditions on a specified project.

These sets of questions were grouped into the first five sections of the pilot survey questionnaire. By arranging the questions under distinct sections by topic and ordering the questions and sections with the easiest questions first, the instrument would be able to accomplish two things necessary for obtaining all the required survey information from respondents. First, respondents could complete the questionnaire a section at a time and feel a sense of progress in completing the questionnaire. This sectional approach also meant that respondents could fit the completion of the various sections of the instrument into their busy schedules by completing a section or two at a time. Secondly, it avoided confusion about the questions as each question was clearly identified as belonging to a defined section with a defined topic or title. Biasing errors were avoided in the *behaviour* questions that used an closed or forced-choice format by providing the respondent with the full range of key alternative answers identified through the literature, and by including "other" as another alternative and thereby allowing respondents to specify their own answer if their answer was not included in the list of key alternatives. Central bias and anchoring (Winkler, 1967b; Hampton *et. al.*, 1973, Chesley, 1975; Wallsten & Budescu, 1983) were minimised in the *belief* questions by first eliciting the extremes of the anticipated distribution (Budescu & Wallsten, 1983; Cooper & Chapman, 1987). The detailed format and content of the questionnaire is presented in appendix 2.

As stated in section 4.3(b), data from Ghana on the types and usage of risk management techniques in the Ghanaian construction industry could not be obtained using the standardised questionnaire presented in appendix 2. Instead, section 2 of the pilot survey questionnaire was used a guide for the series of semi-structured interviews that were held during the main Ghana survey. At each interview, key areas for discussion were highlighted and groups of open-ended questions within these areas asked. Respondents were given the freedom to talk generally and in as much detail as they could in responding to these questions. The key groups of questions asked during the interview were:

Techniques for assessing risks at the pre-construction stage:

- Organisation/composition of the risk identification team
- Methods used for identifying risks
- Methods for assessing risk likelihoods
- Methods for assessing risk severity
- Methods for quantifying risk impact

Risks handling during project execution:

- Methods for dealing with economics risks (fluctuations/Variations)
- Methods for dealing with contractual risks, specifically:
    - Project completion delays caused by client
    - Delays in payment by client

Causes/sources of key contractual risks:

- Project completion delays
- Delays in payment by client

(b) Risk Perception Survey Questionnaire

As discussed earlier in section 4.3(c), the development of the first instrument that aimed at measuring risk perception among construction experts begun with a desk-study of construction accidents, injuries and incident investigation records and statistics of the Health & Safety Executive of the United Kingdom. The purpose of the desk-study was to establish the "actual" or "real" recorded occurrences of the following groups of risks or risk events:

(i) the most commonly occurring risks/accidents during construction
(ii) the least commonly occurring risks/accidents during construction
(iii) the most fatal/severe risks/accidents that occur during construction
(iv) the least fatal/severe risks/accidents that occur during construction

In total, nine risks/accidents were selected from these groups of risks:

- Exposure to an explosion

- Trapped by something collapsing or overturning
- Contact with electricity or an electrical discharge
- Exposure to or contact with harmful substance
- Contact with moving machinery or material being machined
- Strike against something fixed or stationary
- Struck by moving including flying/falling object/vehicle
- Fall from a height
- Injured whilst handling, lifting or carrying

This set of nine risks/accidents formed the basis for a Risk Perception Survey Questionnaire designed to elicit the beliefs of construction experts regarding the occurrence and severity/fatality of the various risks/accidents (see Appendices 3 and 4). Thus, the study used the actual data about the occurrences and severity of the nine risks to calibrate the estimates of the experts about the same risks. Fatality was used as a measure of risk severity since there is a direct relationship between fatality of an accident and its impact on the project. For example, an accident that result in the death of a worker will have a greater impact on the project (e.g. temporary project suspension, financial compensation to the bereaved family, etc) than one that results in a minor injury to a worker (e.g. on-site treatment at the Site Office, day-off from the site, etc). This calibration coupled with the personal information and risk experience of the experts would lead to the nature of risk perception in construction and thereby demonstrate part (a) of the underlying assertions of this part of the study. This part of the study is similar to the works of others such as Slovic *et al.* (1980).

By calibrating the estimates of the experts about the risks using actual information available on those risks, the study would prove that expert estimates are not necessarily always "factual" or accurate, (otherwise their estimates about risks should closely match the actual recorded values) and that their perception of the risks plays a major role in determining the estimates they provide about the risks.

Apart from questions seeking attributes about the respondents, the questionnaire essentially asked open-ended *belief* questions to which respondents were to provide their own estimates. Clarity in the answers sought was provided by asking respondents to estimate their beliefs given a normal year and also given the worst case scenario (disastrous year).

(c) Risk Likelihood and Impact Survey Questionnaire

Like the Risk Perception survey questions, the risk likelihood and impact questionnaire mainly asked open-ended *belief* questions to which respondents were to provide their own estimates. The survey used a "relative likelihood" method (Moore & Thomas, 1976; Chapman & Ward, 1997) and aimed at eliciting direct estimates of probabilities (associated with the occurrence of payment delays in an international project described by a vignette) that would form the extremes of the probability distribution, and also the key intermediate values of the subjective prior probability distribution. This approach was considered much more favourable in the light of evidence from Quigley *et al.* (1996), O'Hagan (1997), the results of the analysis of the Pilot Survey results, and the pre-testing of the schedule which highlight difficulties faced by engineers in assigning prior distributions to measures in typical Bayesian fashion. The "relative likelihood" method is explained in chapter 5. In developing the questionnaire schedule, central bias and anchoring (Winkler, 1967b; Hampton *et. al.*, 1973, Chesley, 1975; Wallsten & Budescu, 1983) were minimised by first eliciting the extremes of the distribution (Budescu & Wallsten, 1983; Cooper & Chapman, 1987). The sectional approach used in the pilot survey was applied to this instrument also for reasons explained earlier.

4.1.3 Vignette/Delphi interview Design

Vignette and Delphi interviewing methodology was adapted into the design for the parts of the study aimed at obtaining data on expert opinions, measuring risk perception and developing the model for eliciting quantified expert opinions about risks. This was done during both the pilot and main phases and through all the five instruments used of the research. Although the Nominal Group approach is believed to offer a superior technique for eliciting expert opinions in a group setting, the approach is most appropriate where the individuals can be brought together to discuss the risk concerned and the estimates given. Traditional Delphi techniques also involve getting together a group of persons with interest in the focus of the research and presenting them with some background to the issue(s) at stake. Each person is subsequently invited to independently generate responses on the issue(s) at stake, and questions/responses raised are discussed the with a view to seeking resolution or consensus through voting, ranking etc. (Robson, 1993). The high expense and impracticality of getting all the experts involved in a group setting (whether in one location or by way of tele- or video-conferencing) made this approach inappropriate for the current research. A hybrid of the individual assessment and Delphi group techniques was therefore adopted as the elicitation technique. Opinions were elicited using an assessment technique that allowed self-elicitation or interviewer-elicitation. However, a number of mechanisms were built into the research strategy in order that similar benefits would be achieved as would be in bringing the group together under the Nominal and traditional Delphi techniques.

Firstly, the research instruments mailed to the pre-qualified respondents were followed with phone calls to the respondents with the aim of ensuring that each respondent had the full explanation of the background to the research and that they fully understood the questions which were being asked. Appointments made to obtain responses either through a telephone interview or a face-to-face interview. To achieve group consensus in the absence of bringing all respondents together in one place, each respondent was asked after the completion of their questionnaire about how they would view their own responses in the light the group aggregate that would emerge from the study. The options were for the respondent to maintain his/her original estimates, adjust the estimates in view of the group aggregate or to accept the group aggregate as being more accurate estimates about the risks. This approach to arriving at the group consensus would also reduce "respondent fatigue" by minimising the number of times a respondent was contacted by the researcher on the same issue. Mechanisms built into the research strategy to overcome the adverse implications of survey interviews are also explained below in section 4.3.4.

Respondents were also given the option of completing the research instrument and returning them to the researcher, in which case the instrument functioned in a manner similar to a structured open-ended questionnaire (see Appendices 2-6 for copies of the instruments).

Traditional vignette techniques present short stories about hypothetical characters in specified circumstances to which the interviewee is invited to respond (Finch, 1987). The vignette in the present research consisted of a brief description of a construction project that provided a background to a set of questions to which the respondents were invited to respond. The responses sought were the respondents estimates of the relative likelihood of occurrences of certain risks associated with the project described in the vignette, and the impact of the risks should they occur. Although, for logical and mathematical reasons, the respondents' estimates were expected to lie within a certain range, they were not confined to specific response categories. Respondents were thus able to express their true opinions on what reflects reality.

Coupled with the sampling strategy described later in this chapter, the use of the vignettes and the Delphi-style interviewing approach present a number of advantages to the research, including the following:

(a) The information to be sought is of a specialised nature and from a specific industry (Building/Civil Engineering). This information is not normally available to the public in an accurate, calibrated and coherent form.

(b) Within this specialised industry, the major repositories of accurate, calibrated and coherent contractual risk information usually those with considerable training in, and direct experience of building/civil engineering construction and/or contracting (i.e., experts).

(c) While risk is inherent in all construction projects, the nature, frequency and impact of the risk will depend on the nature and context of the project in question. Thus, the probabilistic information being sought needs to be set in a context in order to enhance validity. The vignette seeks to provide the context within which experts provide their responses.

(d) The interviewing technique is suitable for a number of reasons that are discussed in more details in a separate section below. Telephone interviewing was used for the most part in order to enhance the speed of responses, reduce costs and allow a larger number of experts to be interviewed.

(e) The vignette technique enabled the development of very concrete questions within the survey format, thereby helping to avoid answers that are simply bland generalisations and impossible to interpret (Finch, 1987). The questions asked and the responses given were context-specific and so expert beliefs and opinions about risk could be discussed in a situated way. This is particularly important since the ultimate objective of the research is to be able develop a model for generating such context-specific estimates about risks for analytical purposes.

(f) Estimating data on real construction projects are highly confidential for competitive and legal reasons. Expert opinions to third parties on specific projects are thus usually extremely difficult to obtain even with the assurance of the highest level of confidentiality. As Finch (1987) argues, the use of the hypothetical vignettes has the effect of making the questions less threatening to the expert personally and to his corporation, and therefore responses much more forthcoming and accurate.

(g) In real life, contractual risks are always set within the complexities of construction projects. While each project is unique with its own levels and types of complexities, certain types of projects present common or core complexities which expert's usually look for to inform their estimation of the risks involved. These include for example level of innovation or technology involved in the project, the rise (height) of the building, etc. By including these core complexities in the vignette, the vignette technique offers an opportunity to explore contractual risks in a way that closely approximates to the way they are dealt with in reality.

(h) As Ranasinghe and Russell (1993) argue, interaction is an essential part of the knowledge elicitation process, the main reasons being to avoid biases and reduce misunderstanding. The works of Hull (1980), Cooper and Chapman (1987) support this view. Following the mailing of the research instrument with an interview ensured that as far as possible, experts had the opportunity to clarify any questions they did not understand. This ensured that all respondents had the same understanding of each question and therefore all responses were to 'the same questions'.

Following the Ghana study, it was decided to redesign the Risk Likelihood and Impact Survey Questionnaire for the UK study to focus on only one of the four risks that the Ghana study had focused on. The main reason for this redesign was the fact that the Ghana respondents displayed difficulty in dealing with multiple risk parameters on the same questionnaire. Respondents in the pilot survey who had to deal with only one risk parameter did not display this difficulty (see section 5.3 for full explanation of the reasons for this redesign).

4.1.4 Dealing with the adverse implications of interviews and Interviewer effects

The research strategy employed a number of checks in its design and implementation to ensure that the adverse implications of interviews and interviewer effects were either removed or reduced to levels of minimal significance. Among these are the following:

(a) *Scheduling of interviews*: One of the problems of conducting research using the interview technique is the comparatively greater length of time it takes to schedule a successful interview. This problem was not a major issue in the research due to the fact that respondents had been pre-selected for the questionnaire survey based on, among others, their interest and willingness to participate in the research. Furthermore, they had expressed their interest in a follow-up interview and therefore expected to be approached for an interview. All follow up interviews for the pilot study, for example, were scheduled in December 1997 and completed by February 1998. The interviews for the main study were either conducted as part of the questionnaire survey (as was the case in Ghana (see section 4.4.2) or following the issuing of the questionnaire and were all completed within planned time frames.

(b) *Interviewer training*: All the interviews were conducted by the author who did not only have significant educational, practical and research experience in the construction industry, but is also very familiar with the respondents' geographical environment. The researcher was therefore well versed in the subject matter of the interview. Furthermore, involving construction experts in both the UK and Ghana in the development of the questionnaire and interviews schedule and subjecting the survey instrument to rigorous academic review prior to the main survey ensured that the right questions would be asked. In essence, the interviewer had sufficient and suitable prior training for the research interviews.

(c) *Reducing biasing errors*: Providing the research instrument to the respondents ahead of the interview gave respondents the opportunity to answer the questions on the schedule in advance of the actual interview. Since the objective of the questionnaire/interview was to elicit expert opinions about specified risks, respondents were free to consult with their peers before arriving at their final estimates for the risks. Responses would therefore be carefully considered answers to the survey questions. Furthermore, since the research was of a specialist nature and conducted by a construction professional solely among construction experts, the language incorporated in the interview instrument were inherent the daily professional perspectives of all the parties to the research. The only anticipated variability is the cultural meanings attached to the same risks but experts from different socio-cultural settings. This of course is variability that the research is seeking to capture. It was considered that this approach to the interviews significantly reduces any biasing errors that result from the personal characteristics of interviewers and variations in interviewer-skill (Nachmias and Nachmias, 1981; Cicourel, 1964).

4.2 Research Sampling

The objective here was to identify recognised experts in the field of contractual risk management from who relevant information could be sought, and seek their co-operation in the research. These steps correspond to stages (ii) and (iii) respectively of the Delphi approach described in section 4.2.2.

4.2.1 Sample Categories

Data collection was targeted at expects within the construction industry. Contracting companies are the essential parties in the construction industry with the first-hand knowledge and experience of project risks. This knowledge is usually held by either the contractor's Contracts Managers or Quantity Surveyors. Construction consultants, especially Project Managers and Quantity Surveyors who are in charge of project cost and time estimation, and contract administration are the next major sources of risk information. In addition, major contractual risks are ultimately transferred to casualty Insurance companies who thus become essential repositories of information on risk frequency and impact. This information is often held in the form of insurance claims, payments or premiums. Nevertheless, it is felt that insurance companies generally err on the conservative side and thus raise the costs of insurance. Contracts Managers, Quantity Surveyors and Project Managers were therefore targeted for sampling. Due to the rarity with which contractual risks occur, the decision was taken to target larger-size companies. The rationale behind this was that larger companies would normally have been in business long enough to have sufficient relevant experience about the risks under investigation and possible some international contracting experience or interest. Another reason was to allow comparability between data from Ghana and the United Kingdom. Generally, only the large companies in both countries tend to get involved in international contracts.

Two sectors within the construction industry were targeted for sampling. These are the

Building Construction (Commercial, Industrial and Public Buildings) and Civil Engineering Construction. This would to bring the benefit of the personal knowledge and experience of the researcher to the research, thereby saving time and cost. Furthermore, the majority of British contractors operating overseas tend to operate in one or a combination of these two major categories. Focusing on the two industrial sectors would therefore bring optimum benefits of the results of the research to the UK construction industry.

4.2.2 Sample Selection: Selective sampling of Experts

The research sample was selected from the population of experts in the construction industry of both the UK and Ghana. The rationale for this approach although obvious, is worth stating here. It was discussed in Chapter 3 how Bayesian analysis relies on a subjective prior probability for the calculation of the posterior probability. It was also discussed how subjective estimates arise from the estimator's knowledge and experience. Although there are varying degrees of knowledge and experience (and hence significant differences in the quality of the estimates from different people), the relationship between subjective estimates and the estimator's knowledge gives subjective estimates an egalitarian attribute since it is accessible to anyone without prequalification. However, for this research, expert selection was considered the most effective approach to elicitation for a number of reasons. Vick (2002) discusses some of the key advantages of the domain-specific expert selection that is applicable to elicitation. These are summarised here.

(a) *Experts are quicker and more accurate with their estimates*: By making extensive use of forward reasoning and combining the process with backward reasoning to confirm decisions reached through forward reasoning (Patel & Groen, 1991), experts are able to be more efficient and arrive at decisions or solutions about a given problem much faster than novices (who tend to rely more on backward reasoning). Forward reasoning involves sequences or progressions of an "if-then" nature and requires more in-depth knowledge about the situation on hand. Although backward reasoning also has an "if-then" character, it works in the opposite direction to forward reasoning and involves checking or screening by a process of matching (Patel, *et al.*, 1996).

(b) *Experts have better self-knowledge*: Reach decisions faster means that the experts often has more time left to apply backward reasoning effectively in checking the accuracy of their decisions (thus making them better at "self-monitoring" (Glaser & Chi, 1988)), and to engage in further questioning and deliberations about the issue at hand.

(c) *Experts anticipate implications of decisions*: by reaching decisions quickly, experts have sufficient time left to think ahead and almost instinctively know what to expect as implications of their decisions. This also allows them to plan ahead.

(d) *Experts have a deeper appreciation of a problem*: Not only do experts have a richer graphical imagery of patterns and better-developed problem representation in their minds, they are also able to sort, characterise and recognise the patterns in problems by their underlying nature than their outward features (which are often the only way novices see problems)

(e) *Experts have better insight to problems*: The combination of the free time left after making a faster decision and their greater repertoire of problem representation means they have more time to devote to understanding the nature of the problem and how best to represent it before a solution or decision is reached. This insight also allows them to change their problem representation and thereby build innovation into their solutions.

(f) *Expertise is domain-specific*: Outside their own specific domains of expertise, experts behave much like novices. Eliciting estimates of construction contract risk from medical doctors with no construction expertise is just not a smart thing to do, although medical doctors are experts in their particular field of medicine!

Vick (2002) also discusses the works of others such as Simonton (1991; 1996) on the development and variations of career expertise over chronological and career ages. According the findings of Simonton (1996) and the analysis of Vick (2002), it would appear that engineering experts reach the height o their expertise between the career ages of ten and thirty-three which corresponds to chronological ages of thirty-five and fifty-three.

Against this background, experts were selected based on the following criteria using a pre-qualification survey instrument (see Appendix 1) mailed or faxed to members of the sample:

(a) Membership of the appropriate recognised professional body. This ensures an acceptable minimum level of professional competence.

(b) Substantial related experience. In view of the relative infrequency of contractual risk, a minimum of ten years of related experience is considered desirable.

The poor reliability of the Ghana postal system and lack of appropriate access to a fax machine by the researcher made it less practical to mail or fax the pre-qualification instrument to targeted experts. Following advice from other researchers both within Ghana and in the UK who had undertaken research in Ghana, a two-step telephone approach was adopted.

Step 1: Initial telephone contacts were made with the selected experts within the companies on the research sample. The objectives of this first contact were:

(i) To introduce the researcher and explain the purpose of the research

(ii) To arrange an appointment for a face-to-face interview on construction risk management in Ghana

(iii) To discuss their further involvement in the research.

Step 2: The face-to-face interview. The objectives of this interview were as follows:

(i) To discuss generally on contractual risks and risk management within the Ghanaian construction industry,

(ii) To solicit their further involvement in the research,

(iii) To leave a set of copies of the survey questionnaires if appropriate, and

(iv) To arrange another appointment to either collect the completed survey questionnaires or to discuss the issues raised by the questionnaires in order to obtain appropriate responses.

The main reason for not seeking to have the questionnaires completed at the first interview was to respect the pressures of time on the experts posed by the busy commercial environment. In addition, this approach allowed them time to study the issues raised by the research in order to formulate appropriate responses.

In the UK, the initial list of experts for the prequalification survey was taken randomly from publications such as the "Chartered Building Company" directory, the "Contractors'

File" and the "Consultants' File". For the UK-based pilot study, 160 experts comprising 40 each of Quantity Surveyors, Project Managers, Construction Managers and Contract Managers were selected. For the main UK study, an initial list of 295 experts was derived from Quantity Surveying, Chartered Building and Civil Engineering firms. A sample size of 98 experts (24 from consulting firms and 74 from contracting firms) were selected using the pre-qualification criteria above.

In Ghana, a full list of registered Contracting Firms was developed from lists supplied by the Ministry of Roads and Transport, The Ghana Highway Authority, The Ministry of Works and Housing and the Association of Road Contractors of Ghana. Ghana contractors are generally categorised into four financial classes in terms of their capacity to undertake various levels of construction projects. Class 1 contractors are the highest-ranking or international contractors. There list of 238 contractors comprised 16 Class 1, 27 Class 2, 128 Class 3 and 67 Class 4 contractors.

In view of the scope of the research and its focus on international projects, the only Class 1 contractors were considered in the sampling. All 16 contractors in this class were included in the research sample. Nine firms from the financial Class 2 category were also selected at random from that list to make the total sample size up to 25. The Quantity Surveyors, Project/Operations Managers or Contract Managers (as appropriate) from these 25 companies were included in the research sample.

In addition, the Ghana Institute of Surveyors (GIS), which is the professional body of surveyors in Ghana, publishes the list of all qualified surveyors and registered surveying firms annually. The full GIS list for 1998 of registered professional Quantity Surveying firms (29 in number) registered with and recognised by the Ghana Institute of Surveyors (GIS) was obtained from the Institute. A list of all consulting firms registered with the Ghana Government (252 firms in all) was also obtained from the Ministry of Road & Transport, the Ghana Highway Authority and the Architectural and Engineering Services Corporation (AESC - the main local consulting body to the Ghana Government). This list was later disregarded since all those on that list who were not on the list obtained from GIS either were not based in Ghana had no risk management expertise. The Principal Partners from all 29 firms on the GIS list were included in the research sample. In Ghana, Principal Partners are usually the most experienced or longest practising professionals in the firm. The total sample size for the Ghana study was thus 54, made of 25 experts from construction companies and 29 consulting Quantity Surveyors.

4.3 Data Collection Strategy

Data collection was achieved through a 4-step strategy. For the Delphi approach, this stage of the research corresponds to stage (iv) of the process described in section 4.2.2.

Step 1: Providing the selected sample with the Research instrument. This was generally done by mail in the UK. In the Ghana-based study, this was done during the second interview (first face-to-face interview) with the expert (see section 4.2.2)

Step 2: The Pre-Elicitation Telephone call. This will be done in about 3-7 days before the elicitation interview. The purpose was to confirm that the experts understood the research instrument and the information it sought to obtain. The telephone call was to ensure that the experts were able to reflect on the issues involved in advance of the interview, and had the opportunity to clarify and matters that they did not understand.

Step 3: The Elicitation Interview. In the UK, this was generally done by telephone. In the Ghana-based study, face-to-face interviews were considered most appropriate. The objective of this interview was either to collect the completed survey instruments or to discuss the issues raised by the questionnaires in order to obtain appropriate responses.

Step 4: Development of Consensus. The responses from the experts were analysed on both individual and group (quantity Surveyors, Project Managers, etc.) basis. Respondents were subsequently provided with telephone feedback on their estimates and the group aggregates. They were then given the opportunity to evaluate their own estimates in the light of the results by maintaining their original estimates, adjusting them or accepting the group aggregates as being more representative of the risk. The objective was to reach a group consensus with acceptable level of variability.

4.4 Data Analysis

Data entry and analysis were done using Microsoft Excel. The first part of the analysis consisted of deriving descriptive statistics relating to the first objective of the research, and some aspects of the second objective of the research. The second part of the analysis applies the "relative likelihood method" (Moore and Thomas, 1976; Chapman and Ward, 1997) to the expert estimates to derive the extremes as well as the main intermediate values of the implied subjective probability distributions. The relative frequency data obtained from construction experts builds triangulation into the data collection strategy and are used to revise the experts' prior distributions in order to generate posterior distributions in accordance with Bayesian analysis (Phillips, 1973). These analyses are discussed in Chapter 5.

4.5 Limitations of the Research Design

The research was designed to overcome most of the disadvantages associated with the methodologies used. This section discusses some of the practical issues involved in the methodology adopted for the research, and the limitations they impose on the results of the research.

4.5.1 Ascertaining accuracy

Expert opinions are recognised internationally and care was taken to select recognised experts based on their professional standing and years of experience. However, these criteria in themselves do not guarantee that the information provided by the experts is totally accurate. This fact is highlighted by the way in which expert estimates for the same project risks tend to vary.

It has been argued that to increase accuracy, one could obtain subjective probability opinions from experts on other risks for which there are sufficient documentedrecords to produce a 'control' probability distribution. The actual distribution generated by each expert's data on these risks can be then compared with this control distribution. The degree of variability of the expert's distribution from the control distribution can then form a basis for making necessary adjustments to that expert's probability data on the main risk that is being studied. Although this will provide a handle on the expert's skill, to be able to make any corrections one will have to be able to show that the expert consistently over or under estimate, that do so by a constant or predicable amount or proportion, and that the likelihood of doing so for the present research is identical. These seem rather very heroic assumptions and the approach probably impractical given the length and time implications the study. It is argued that since the data being sought are probabilistic estimates and not discrete values, this threat to accuracy is not significant.

4.5.2 The effect of time and High-impact events on expert opinion

Expert experience and opinions are built up over time - longitudinally - and are not set within a specified time range or snapshot. Past events of high impact can therefore create a perception of a higher frequency of the particular high-impact risk that the expert experienced which may be far removed from reality. This fact is supported by the work of Slovic et al, (1980). Furthermore, the frequency (and impact) of risk is affected by other factors such as the general level of technology and risk knowledge and understanding within the industry. Expert opinions on risk probabilities are generally historical, and with the rapid development in technology and communication, may not necessarily be effective indicators of risk probabilities for the present or the future. This raises a question on the generalisability of the research findings. A number of options were considered in order to get a handle on these issues. One could ask about such expert experiences and how they are viewed when making the estimates in hand. One could also ask the experts to give an account of the way in which they come to their conclusions on probabilities or the extent to which these probabilities have been affected by technological changes. Analysis of such extra information can then be treated as annotations to the main analysis. It was considered however, that seeking such extra information from experts required such additional commitment from them that was difficult to obtain in the context of a doctoral research.

4.5.3 Inconsistency of additional assumptions by experts

Finch (1987) argues that respondents can 'fill' in additional details to the vignette. Doubt about the consistency of these assumptions raises questions about the generalisability of the findings. Although the vignette provides a common basis for expert responses, it is by no means a detailed project description, and in the absence of full project details, experts make assumptions, whether consciously or unconsciously, of some aspects of the project. While the concern here is true, the reality is that in estimating experts seek to make only certain key assumptions about the project where data is unavailable. The pre-testing of the vignette ensured that these factors were included to minimise the need for additional assumptions by experts and thus enhance consistency of responses.

4.6 Summary

The focus of this chapter on the development of the research approach adopted for this study and the rationale for such a design. In addition to ensuring the validity of the research as a scientific study, the research design also aimed at demonstrating how appropriate data for the rigorous analysis contractual risk can be easily obtained and at no significant extra cost. Thus, the first part of the chapter reviewed literature that address some of the philosophical and methodological issues in the broad field of social research that have a significant impact the current research. The rest of the chapter discussed various aspect of the research methodology including nature of the research data and data collection and the analytical approach adopted for the study. The last section discussed some of the practical issues involved in the research methodology and the limitations they impose on the results of the research.

The next chapter presents the results and analysis of the survey among construction experts in the United Kingdom and Ghana using the research methodology described in this chapter. The first part discusses the practice of risk analysis in construction and the key risk analytical techniques used in the industry. The second part discusses the results of the survey on risk perception and evaluates how the adverse effects of individual perception expressed in subjective estimates of risk can be overcome by the aggregation of expert opinions. The last part presents the analyses and development of expert opinions elicited by the survey into subjective probability estimates and the application of Bayesian analytical approach to the subjective estimates generated by the research.

CHAPTER 5

RESEARCH RESULTS AND ANALYSES

5.0 Introduction

The main aim of the research was to provide better understanding of the nature of contractual risks and techniques that can be applied to their rigorous and effective analysis. In particular, it sought to investigate the use of elicitation and probability analysis techniques for quantifying expert opinions as subjective probabilities for use as input variables in contractual risks analysis. To achieve this objective, the research sought to investigate the current practices of risk management, and study how subjective expert opinions and perceptions about risks influence the risk management effort and hence project management. The objectives of the study were thus stated as:

(a) To conduct a review and survey to establish the types of risk management techniques currently used in the construction industry, and the extent of their use;
(b) To investigate risk perception in the construction industry and its impact on project performance (price).
(c) To develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception risk perception on individual estimates of risk, and provides these opinions as an input variable to the systematic and effective analysis of contractual risks.

Having therefore developed the theoretical foundations of the study in the preceding chapters and indicated some of the factors motivating this study, the present chapter discusses the main findings of the research survey on which conclusions of this study are based. Section 5.1 presents the findings and analysis of the first part of the Pilot survey conducted to assess the extent and frequency with which common techniques for identifying and analysing risks are applied to contractual risks by various professions within the construction industry. In particular, the study assesses whether the predominant practices adequately reflects the nature of contractual risks and the significant personal biases and perceptions to which their analyses are subjected. Section 5.2 which presents the second part of the Pilot survey results and analysis discusses the development and testing of the model for eliciting subjective expert beliefs as quantified inputs to contractual risk analysis. It also discusses the relative likelihood method used in eliciting and analysing the expert beliefs. In section 5.3, the results and analysis of first part of the Main Surveys which conducts an investigation into risk perception in the construction industry and its impact on project performance are discussed. Section 5.4, discusses the findings and analysis of the survey designed to apply the elicitation model tested and refined through the Pilot Survey, to elicit subjective probability estimates from construction experts for use as input variables to contractual risk analyses. The specific limitations on the analysis by the survey data are presented in section 5.5. For each section, the background of some of the computations applied to the results of the survey is given prior to the discussion of the survey findings to which the computations are applied. The chapter is concluded with a summary in section 5.6.

5.1 Contractual risk analysis practices among the construction professions

The section presents the results and analysis of the Pilot survey regarding the practice of risk management among the construction professions in both the UK and Ghana. Sections 5.1.1 - 5.1.6 discuss the results of the UK pilot study. Although the comparable study done in Ghana was conducted as part of the main Ghana study, an overview of the practices in Ghana is presented under this section for two reasons. Firstly, the interviews that generated the data analysed here were done separately from the rest of the interviews designed to apply the elicitation model (see section 4.3.2(b). Secondly, discussing the results from the two countries in the same section will foster ease of comparison between the two countries. The results from Ghana are thus presented in section 5.1.7.

As stated in section 4.2.1 the purpose of this part of the study was to test the assertions that although applications and use of systematic and rigorous probabilistic methods to risks in other industries can only point to the enormous potential that such methods present to the construction industry,

(a) there is very little application, if any, of systematic and rigorous probabilistic methods to contractual risk in construction;
(b) analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques.

As discussed in section 4.2.1, these assertions are in essence theoretical constructs that needed testing with real life responses so that major conclusions drawn from the research would be empirically based, induced from the analysis of the data collected. This part of the research therefore adopted a positivist approach, using a standardised questionnaire as the main method of primary data collection and analysis. The survey instrument used for this part of the study is provided in Appendix 2.

Before proceeding to use the survey results to test the hypotheses, it is necessary to explain some basic computations applied to the data collected. An inspection of sections 1-3 of the Contractual Risk Management questionnaire (Appendix 2) shows that apart from questions seeking factual information about respondents (sections 1 and 2), the questions asked respondents to indicate how often (on a 5-point scale of: *Never, Occasionally, Frequently, Very Frequently, Always*) they use any of the key techniques and methods identified through the literature for identifying and analysing contractual risks. Answers to factual questions are in the form that can be readily applied in analysis of the respondents and thus the various professions within the construction industry. Frequency tables were also constructed and inferences based on the results. For the analysis of responses to the 5-point scale questions, first a carefully considered weight reflecting the degree usage of a particular technique being measured is assigned to each possible answer. Thus, responses were weighted according to the following scale:

Response	***Scale Value***
Always	4
Very Frequently	3
Frequently	2
Occasionally	1
Never	0

Using these scale values, the responses were then converted into rating values that are later plotted to provide a summary view of the risk identification and analysis practices within the industry. The total rating value (R) for a risk identification or analysis technique, T, was computed as:

$$R_T = \sum_{i=0}^{4} i n_i \qquad \text{(Equation 5.1.1)}$$

where is n_i is total number of respondents assigning scale value i to technique *T*. As an illustration, consider the response to the question on how often respondents used "pondering" in seeking to identify things that could go wrong on a project. Details of the responses and the corresponding rating scale values provided by the respondents are provided in Table 5.1 below. Thus from Equation 5.1.1, the total rating value for pondering is computed as 86 with a mean rating value of 2.97:

$$R_T = \sum_{i=0}^{4} in_i = (4x13) + (3x8) + (2x3) + (1x4) + (0x1) = 86$$

Table 5.1.1: Respondents' Ranking of their use of Pondering for Risk Identification

Response	***Scale Value***(i)	***Number of assigning value***(n_i)	***Rating Value***(in_i)
Always	4	13	52
Very Frequently	3	8	24
Frequently	2	3	6
Occasionally	1	4	4
Never	0	1	0
Total No. of Respondents $(\sum n_i)$		29	
Total Rating Value (R_T)			86
Mean Rating Value $(R_T/\sum n_i)$			2.97

The approach and rating scale is similar to that used by Burchett *et al.* (1999) in the analysis of the extent of risk identification within electrical supply projects, and by Antwi (2000) for the analysis of urban land markets in Ghana. It should be pointed out that since the rating scale is applied in the same manner across all responses to the different techniques, direct comparisons of the resulting rating values can be made between different techniques and different sets of questions. Mean values calculated using this scale thus also represent the measures of central tendency of the usages of the different techniques Burchett *et al.* (1999).

5.1.1 Characteristics of the Pilot Survey Respondents

To enable a cross-cultural analysis between Ghana and the UK, an attempt was made to obtain similar survey data from Ghana. The time and logistical constraints of the study made it impractical to conduct a questionnaire surveys in Ghana. The Ghana survey therefore consisted of interviews (involving about 47 construction professionals) which sought to obtain the similar type of data to the ones that the UK Pilot Survey sought to collect. The results of the interviews are summarized separately in section 5.1.7. The rest of section 5.1 presents the results from the UK Pilot Survey.

A summary Based on the responses to Section 2 of the Pilot Survey questionnaire, the breakdown of the responses from the 160 questionnaires sent to the selected professionals (see section 4.4.2) is given in Table 5.1.2. The "Other" category represents respondents who are now working in different professional capacities from the ones for which they were selected. They include a Building Manager, an Estates Director, two Managing Directors and a Facilities Manager. Seven other participants responded to indicate that they were unable to complete the questionnaire for a number of reasons (e.g. lack of relevant experience, busy personal schedule, etc). These were not included in the analysis. Although the effective response rate of 18% appears small, it is consistent with survey responses within the construction industry generally and in the UK specifically (Simister, 1994; Baker & Smith, 1999 and Burchett *et al.*, 1999), and not surprising for a questionnaire survey (Nachmias and Nachmias, 1981).

Table 5.1.2: Profile of survey sample

Profession	*Number selected*	*Number Responding*	*Percentage Responding*
Construction Managers	40	2	5.00%
Project Managers	40	4	10.00%
Quantity Surveyors	40	18	45.00%
Contracts Managers	40	1	2.50%
Others*	0*	4	10.00%
Total Respondents	160	29	18.13%

* *Although the sampling strategy targeted only the four professions above based on the sources of the sample, the professions indicated by the actual respondents on the questionnaires included other professions that were not originally targeted. The 'Other' category therefore refers to professionals such as Directors of companies, Property Developers and Legal Consultants who felt that their current job functions did not fit accurately into any of the four main categories indicated on the questionnaire.*

The characteristics of the survey respondents are presented in Figures 5.1.1 to Figure 5.1.4. As Figures 5.1.1 and 5.1.2 show, although equal numbers of subjects were selected from four categories of experts, the majority of respondents were either Quantity Surveyors (over 62% of respondents) or and/working with a Quantity Surveying firm (about 33% of respondents). This may be reflective of two issues. First, Quantity Surveyors stand to benefit the most and therefore have the highest interest in the research. Second, as one of the primary repositories of construction cost and risk information, Quantity Surveyors are much more favourably placed in providing the sort of information required by the study. The impact of this characteristic and the relevance of the survey findings would be appreciated further when it is considered that in view of the historical development of the which is relatively new Project Management profession within the construction industry in the UK, the majority of experienced Construction Project Managers are Quantity Surveyors who have moved on to become Project Managers.

The low response rate from Construction Managers was mainly attributed to lack of either relevant or depth of experience in the subject matter of the survey or lack of time. These were also the main reasons given for non-response by the other survey subjects (a total of 131 for the pilot survey) who were unable to participate in the study. Two facts explain this reason. The first is that in view of the relative infrequency of contractual risks, experts would need to have been in the field that provides them with experience of the risks for significant number of years for them to be able to make informed judgements about the risks. Ten years of experience was considered a minimum by the study (see section 4.2.2). Secondly, although the sampling of the experts was based on this criteria of 10 years of minimum experience, in most of the cases among the non-respondents, the questionnaire had been passed on to a junior member of the staff of the company because the participant originally selected could not find the time to complete the instrument. The problem was that the junior members of the staff had an average range of experience between 2-5 years and thus did not feel competent enough to complete the questionnaires.

The second explanation is a classic one in the industry although it is the belief of the current author that its stems more from apathy caused by the belief that much of academic research related to the construction have in the past not been readily beneficial to and usable by the industry. The first explanation is credible because traditionally, construction managers are more involved in the project execution phase of the project rather than the planning phase where much of the risk management functions are concentrated. Similarly, Contracts Managers are traditionally concerned with the administration of the contract rather than the planning or actual execution of the project works. It is also worth noting in figure 5.1.1 that categories given are not mutually exclusive. The industrial sector stated represent the sector in which the respondent does the majority of his professional work.

Figures 5.1.1 - 5.1.4 summarises the analysis of the respondents by industrial sector, profession, years of experience and annual turnover of their company respectively. As Figures 5.1.1 indicates, the majority of respondents came from the Quantity Surveying, Building Construction and Property Management sectors (over 67% of the respondents). With the exception of the 2 respondents who were Construction Managers, all the respondents had more than 10 years of industrial experience (94% had more than 15 years of construction experience), and over 80% had more than 10 years of experience in their current profession within construction (see figure 5.1.3). This high percentage of highly experienced respondents is very significant in the light of the works of Simonton (1996) and Vick (2002) discussed in section 4.4.2, and lends further credence to the relevance and the accuracy of the information obtained. It is worth noting that each of the 131 experts who could not participate in the study due to lack of experience had 2-5 years of construction experience. These people were asked by the participants originally selected for the survey, to complete the survey questionnaires on their behalf.

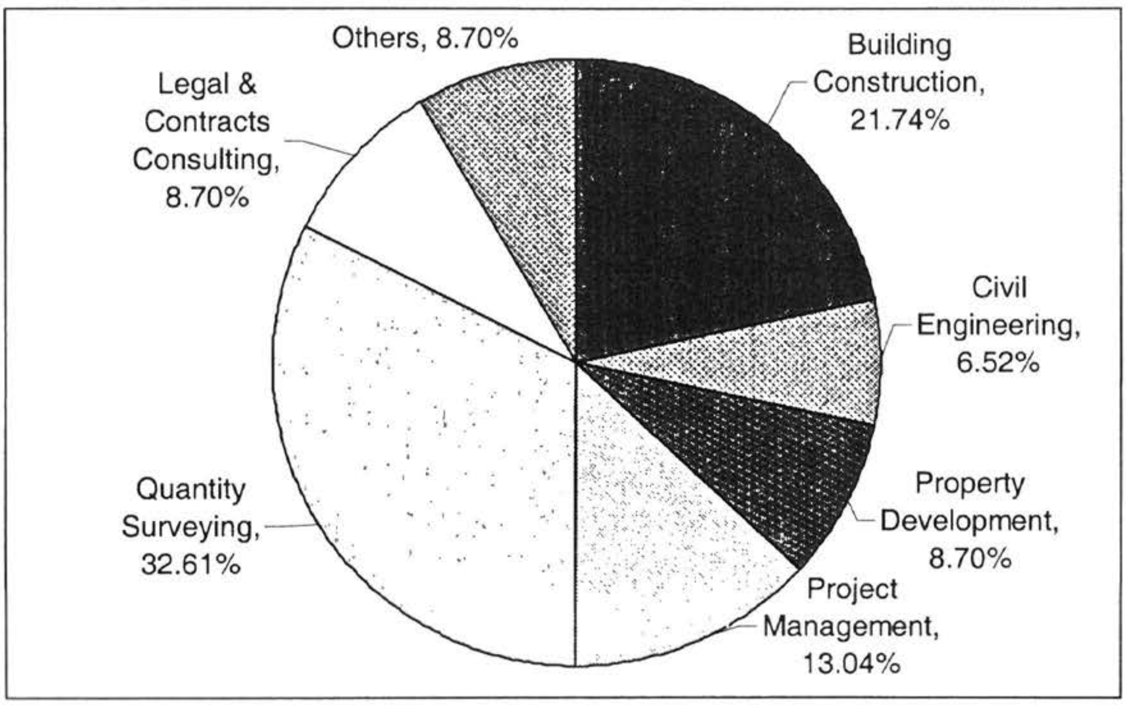

Figure 5.1.1: Respondents by Industrial Sector

It is interesting to note that the annual turnovers of almost 70% of the respondents (see figure 5.1.4) was less than five million pounds. This is contrary to the belief that formal risk management approaches could only be afforded by larger companies due to perceived extra cost of implementing such systems.

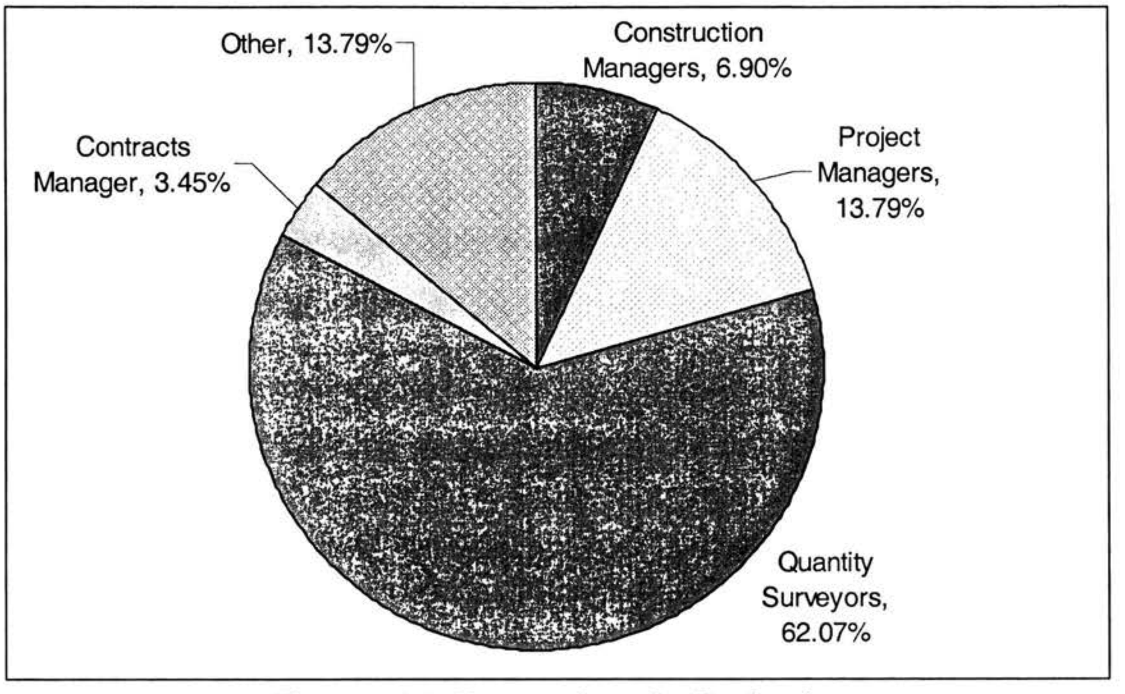

Figure 5.1.2: Respondents by Profession

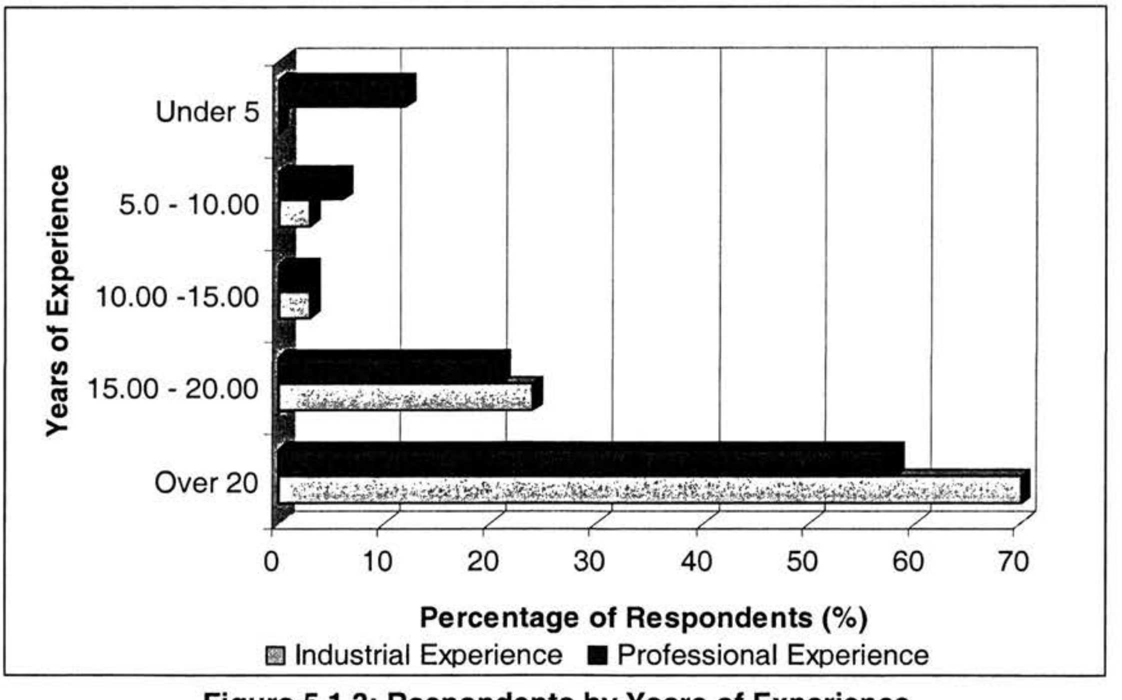

Figure 5.1.3: Respondents by Years of Experience

Due to the small numbers of participants from the Construction and Contract Management backgrounds (see table 5.1.2 and figure 5.1.2), the analysis of their data is not discussed in this Chapter. The 'Other' category refers to professionals such as Directors of companies, Property Developers and Legal Consultants who felt they did not fit accurately into any of the four main categories being studied. Again, due to the fact this category does not fit into any specific professional category, the analysis of its data set is not discussed in this report.

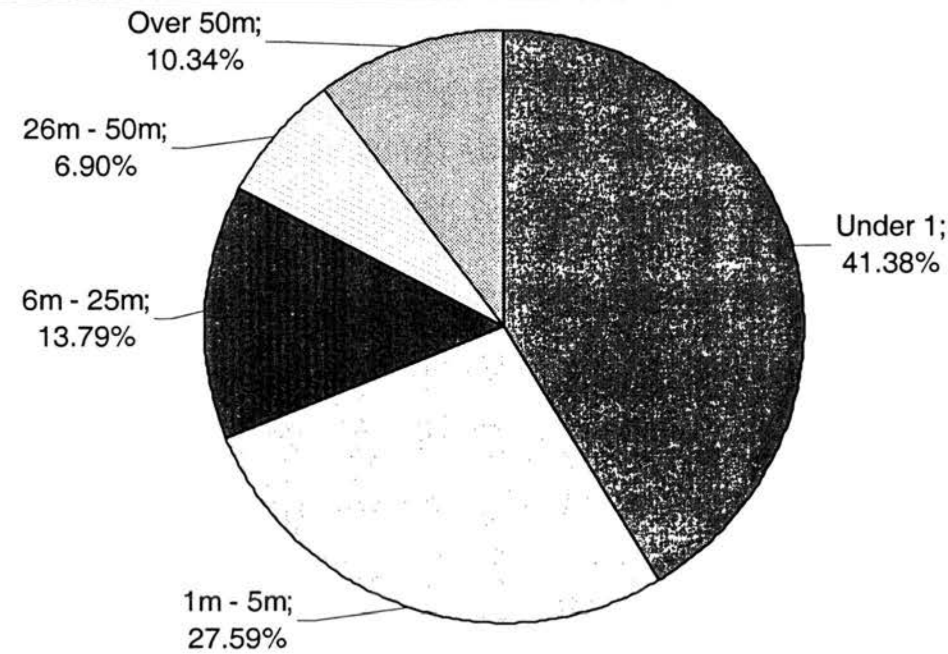

Figure 5.1.4: Respondents by Company Annual Turnover (£)

5.1.2 Extent of use of Risk Assessment approaches

Figures 5.1.5 to Figure 5.1.7 summarise the predominant risk assessment approaches used by the survey respondents. Among the four professional categories studied, the task of risk assessment appears to be undertaken predominantly by one individual within the organisation. This was used by about 76% of the respondents. This is particularly so among Quantity Surveyors about 83% of whom use this approach. This usage is consistent with levels of usage within the Quantity Surveying sector of the industry where over 93% of respondents use this approach compared to the 13% who use the In-house Multidisciplinary Group approach. Whereas a case justifying this practice can be made in view of the high level of experience of those involved in the study, it has been generally argued that the complex and dynamic nature of construction projects requires more experience in identifying project risks than one expert can provide (Ashley, Stokes &

Perng, 1988). Modern construction spans several industries. Even within the construction industry itself, technological advancements have created such myriad specialisations in product and component technologies that no one professional can any longer claim to be a sole repository of construction risk knowledge.

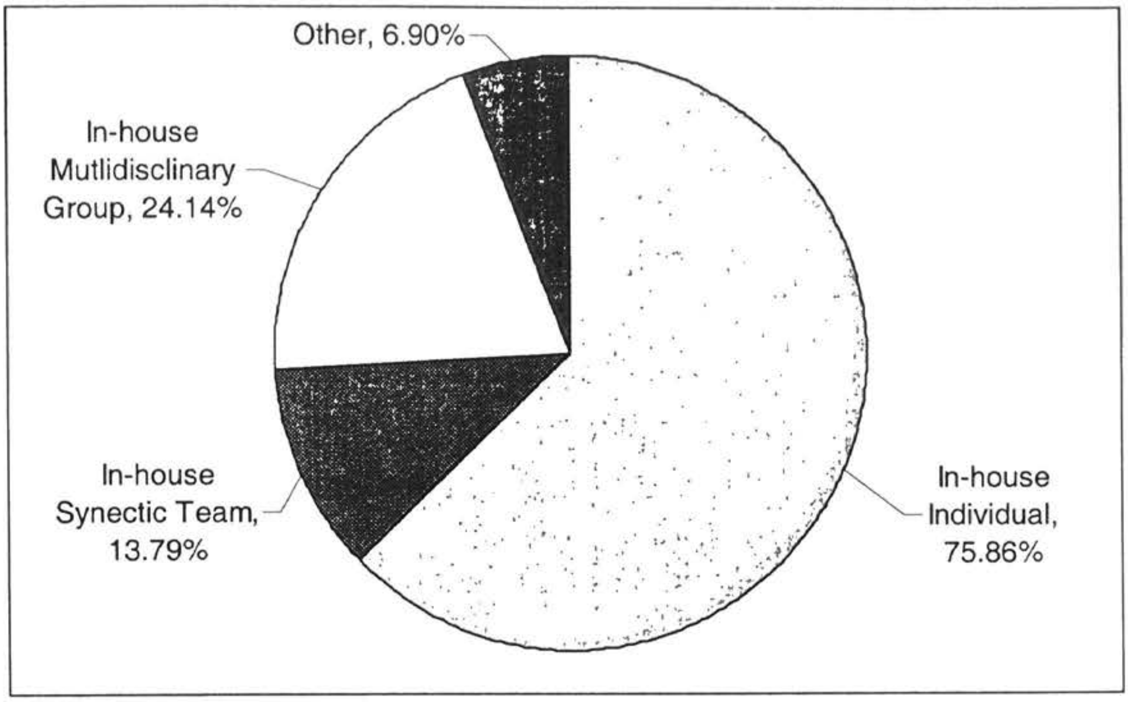

Figure 5.1.5: Overall Usage of Risk Assessment Approaches

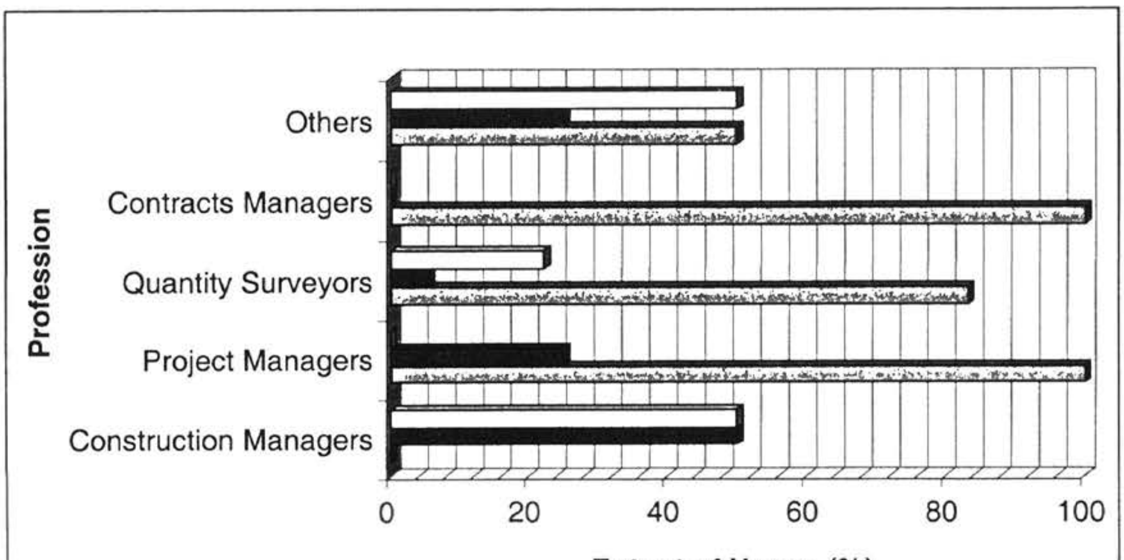

Figure 5.1.6: Usage of Risk Assessment Approaches by Profession

The In-House Individual approach is the most susceptible to personal biases and perceptions and would be considered the least suitable among three main assessment approaches for contractual risk analysis, unless the projects being analysed were very familiar, highly identical or repetitive of previous projects for which rigorous risk analysis had previously been conducted. This hardly ever happens in construction.

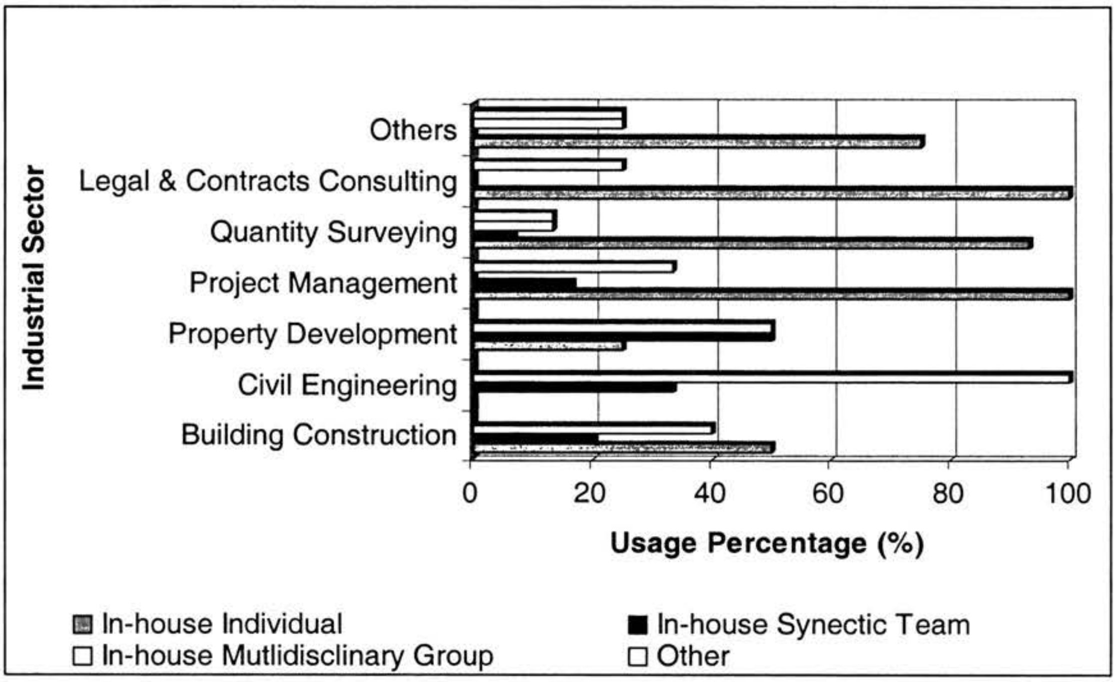

Figure 5.1.7: Usage of Risk Assessment Approaches by Industrial Sector

The use of the In-House Multidisciplinary Group approach appears to be the standard practice within the Civil Engineering sector (100% of respondents). This must however, be interpreted against the background that the Civil Engineering sector makes up only 6.5 % of the respondent population (see figure 5.1.1).

5.1.3 Extent of use of Risk Identification Techniques

Table 5.1.3 and Figures 5.1.8 to 5.1.10 summarises the results of the survey concerning the use of risk identification techniques in the industry. From these results, "pondering" appears to be the key risk identification technique employed in the construction industry. All the respondents use this technique to varying degrees (rating values: mode = 4.00; median = 3.00; mean = 2.97; inter-quartile range = 2.00 - 3.00) and about 85% of respondents use it at least 'frequently'. This is followed by the use of checklists. Like "pondering", all but one of the respondents uses this method, about 72% of respondents using it at least "frequently". It is worth noting that the risk identification techniques listed in the survey instrument appear to be the only ones with which that the greater majority (97%) of the respondents were familiar. Among the risk identification techniques, Synectics and Expert Interviews are the least used among almost all the professions. These results are consistent with results from the analysis by industrial sector.

Table 5.1.3: Overall Usage (Mean Rating Values) of Risk Identification Techniques

	Risk Identification							
Profession	**Pondering**	**Brainstorming**	**Synectics**	**Checklist**	**Risk Lists**	**Prompt Lists**	**Expert Interviews**	**Others**
Construction Managers	1.00	2.50	0.50	3.00	0.00	0.50	0.50	0.00
Project Managers	3.25	1.75	0.50	1.75	1.25	1.00	0.25	0.00
Quantity Surveyors	3.17	1.89	0.39	2.17	0.89	2.06	0.94	0.22
Contracts Managers	4.00	2.00	0.00	1.00	1.00	3.00	0.00	0.00
Others	2.50	1.75	0.75	2.75	1.75	1.50	0.25	0.00
Overall Mean Rating Value	2.97	1.90	0.45	2.21	1.00	1.76	0.69	0.14

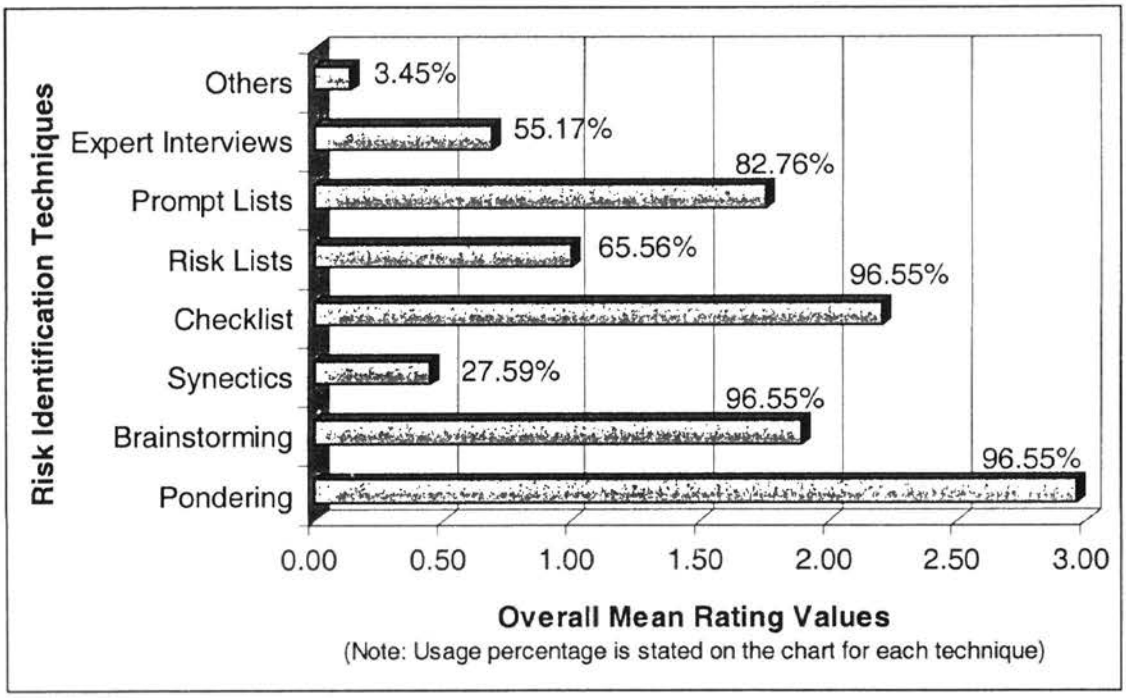

Figure 5.1.8: Overall Usage of Risk Identification Techniques

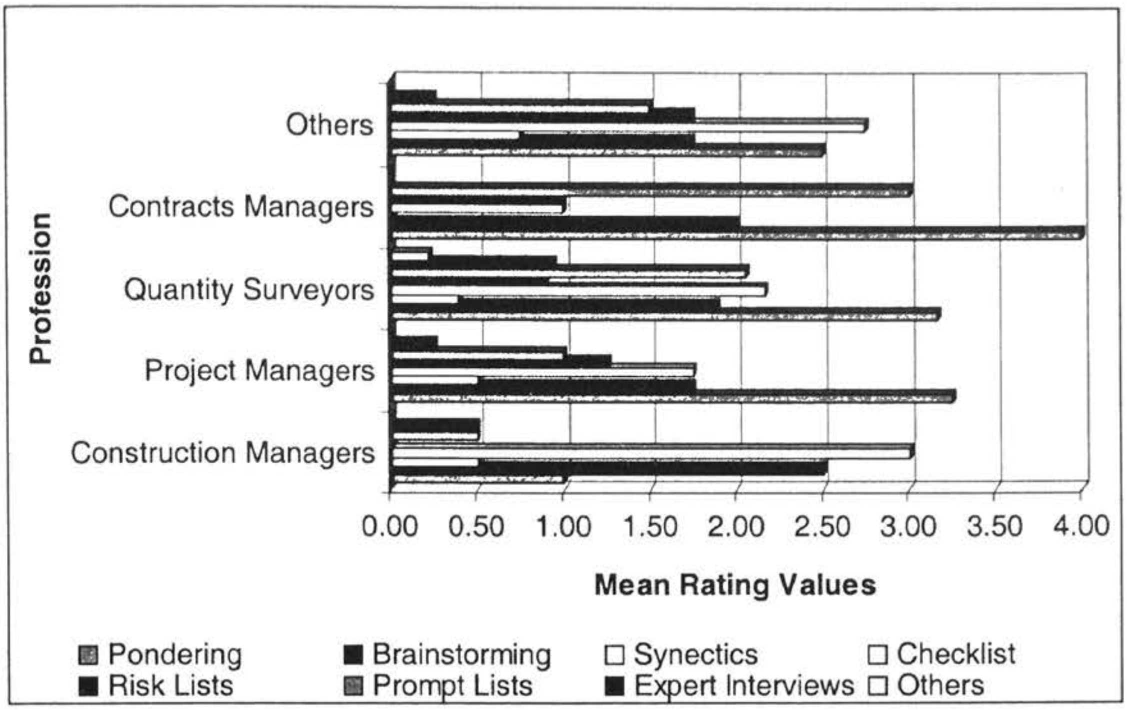

Figure 5.1.9: Usage of Risk Identification Techniques by Profession

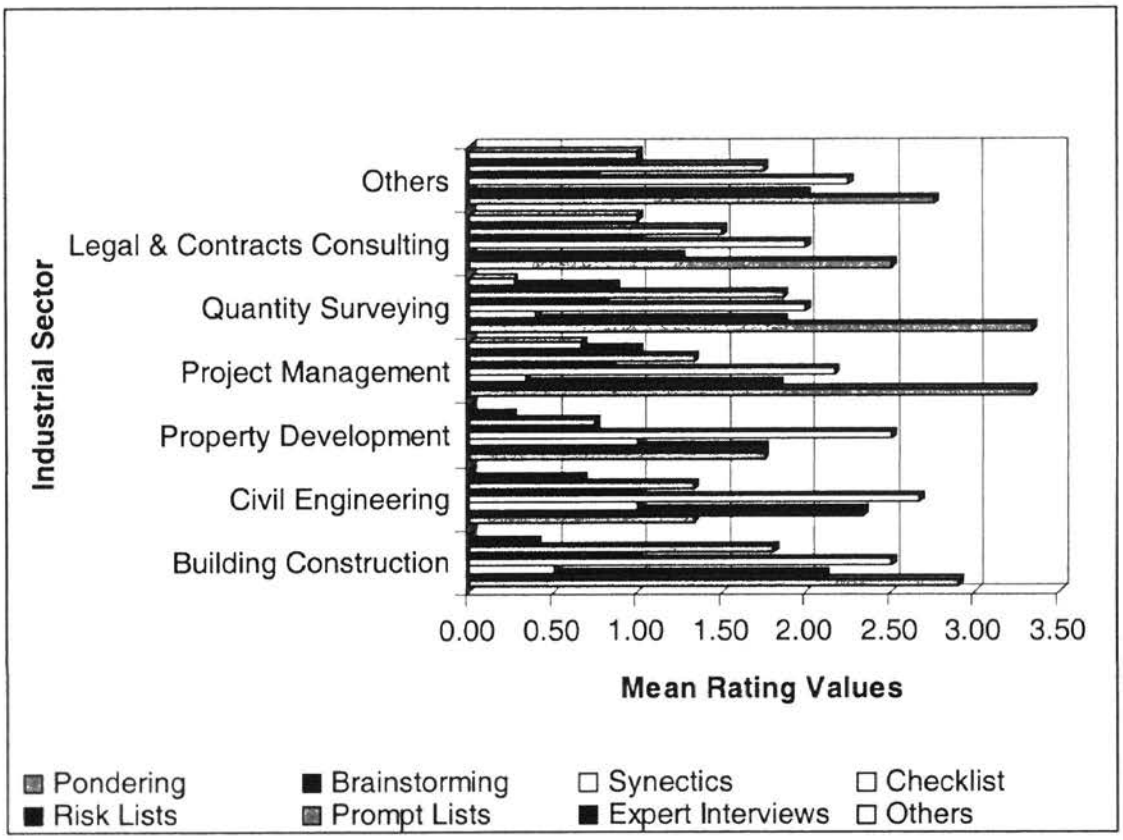

Figure 5.1.10: Usage of Risk Identification Techniques by Industrial Sector

The higher usage of Pondering and Checklists (compared to Synectics and Expert Interviews) can be attributed to the ease with which one person can use such techniques. In terms of corporate economics, they are cheaper techniques too!

While the practice of pondering and checklists are good approaches to risk identification, it is doubtful is they can adequately highlight all the risks in a complicated construction project, especially if these techniques are being used by just one individual on the project. As stated earlier, the multidisciplinary, cross-industrial and technologically specialised nature of modern construction makes it inappropriate for one professional to assume sole responsibility for the identification of construction project risks.

5.1.4 Extent of use of Risk Likelihood and Impact Assessment Techniques

Figures 5.1.11 to 5.1.16 summarise the results of this area. The predominant practices here (including practices among the professions and in different industrial sectors) involve the use of scaling methods and subjective probability assessments. This is not surprising, as contractual risks by their nature do not lend themselves easily to the use of quantitative probability assessments. However, the fact that these techniques are not 'always' or 'very frequently' used would seem to confirm the work of Hayes *et. al.,* (1986) which reported that contractors hardly assess the separate risks that they are asked to carry, but resort to the addition of a single percentage cost contingency to give an overall impression of their perception of the total risks that they are asked to carry. These findings are also consistent with the findings of Simister (1994) in his survey of construction project risk analysis techniques used in the UK, and those of Burchett *et al.* (1999)'s worldwide survey of risk management practices among electrical supply companies. It is interesting to note that although scaling methods and subjective probability assessments are used in risk likelihood and impact assessments, these assessments are generally conducted using the In-house Individual approach. This combination fails to maximize the potential benefits of the subjective probability approach in particular as the assessments become heavily subject to effects of the personal perceptions and biases of the individual (see section 5.1.2). After over a decade of technological, research and management advances, the construction industry does not appear to have shifted very significantly from old practices. This is in spite of the introduction of the Construction Design and Management (CDM) Regulations and the recommendations of the Construction Industry Advisory Committee for the industry to adopt a qualitative, scaling assessment as an industry basic level of risk frequency and severity (CONIAC, 1995).

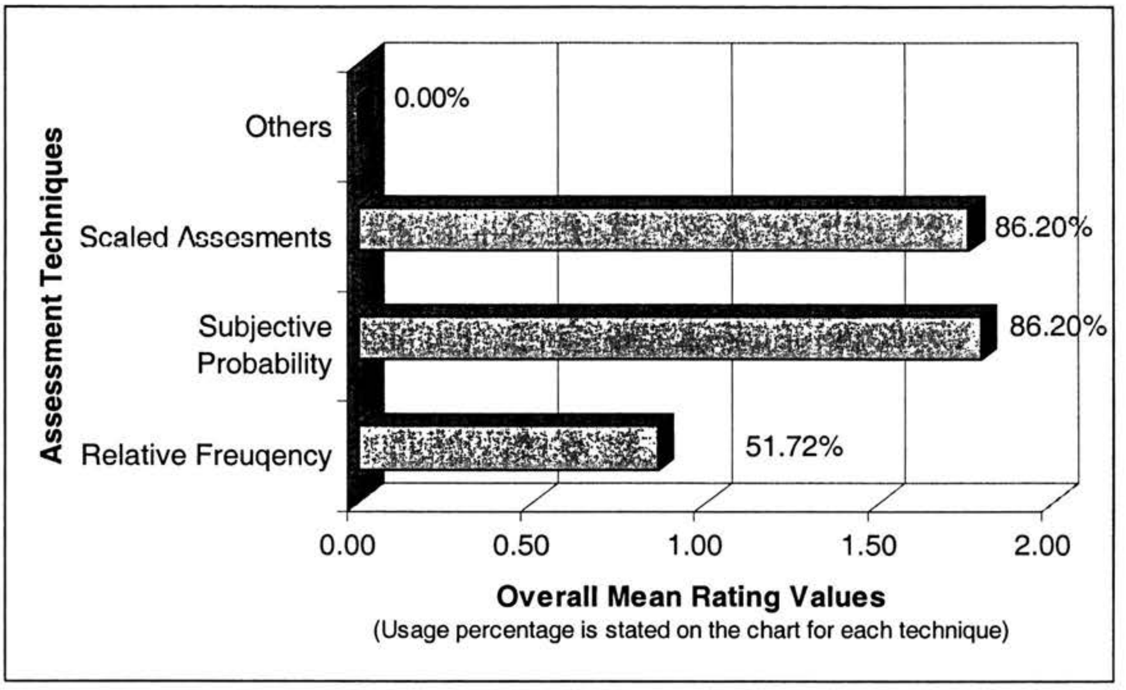

Figure 5.1.11: Overall Usage of Risk Likelihood Assessment Techniques

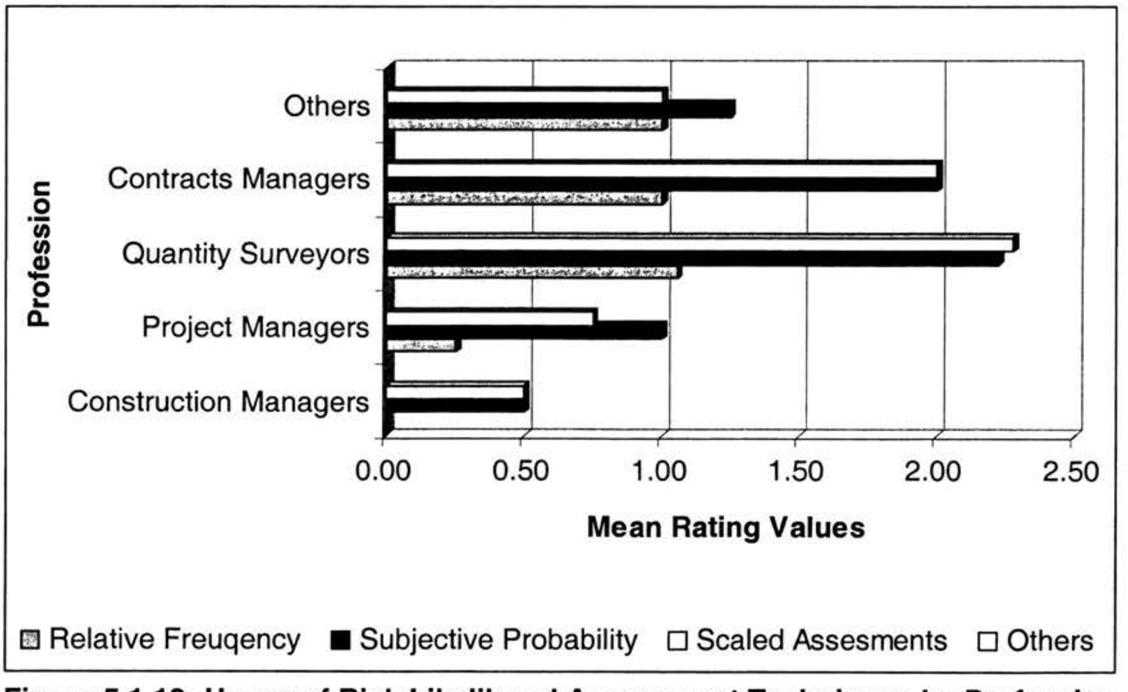

Figure 5.1.12: Usage of Risk Likelihood Assessment Techniques by Profession

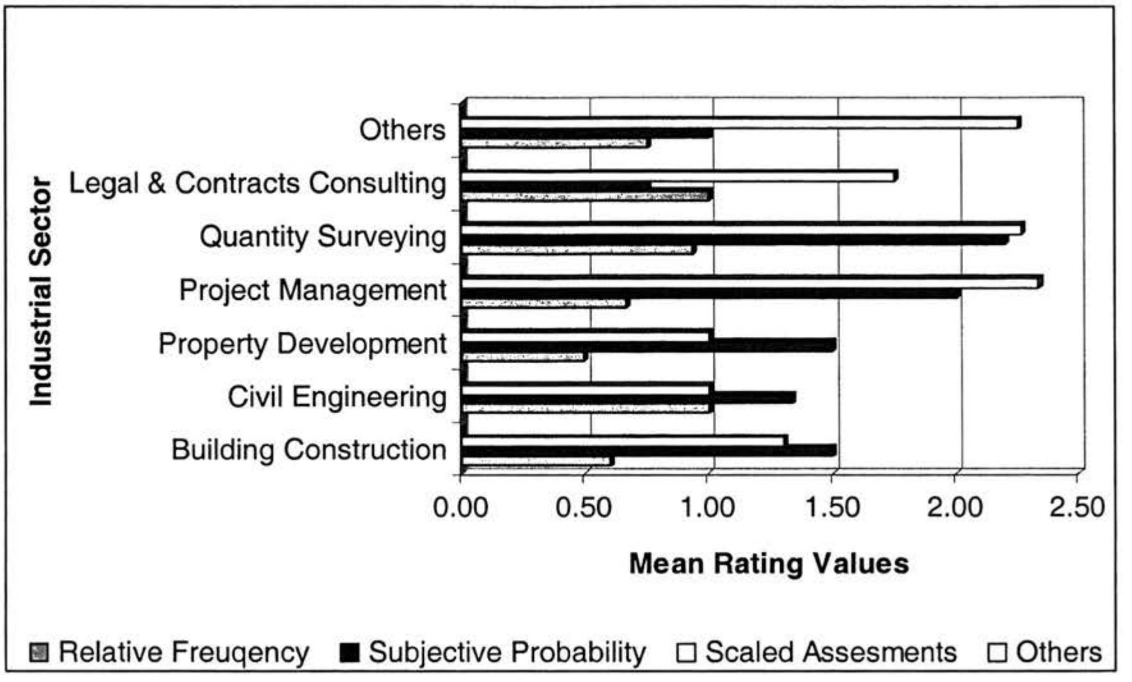

Figure 5.1.13: Use of Risk Likelihood Assessment Techniques by Industrial Sector

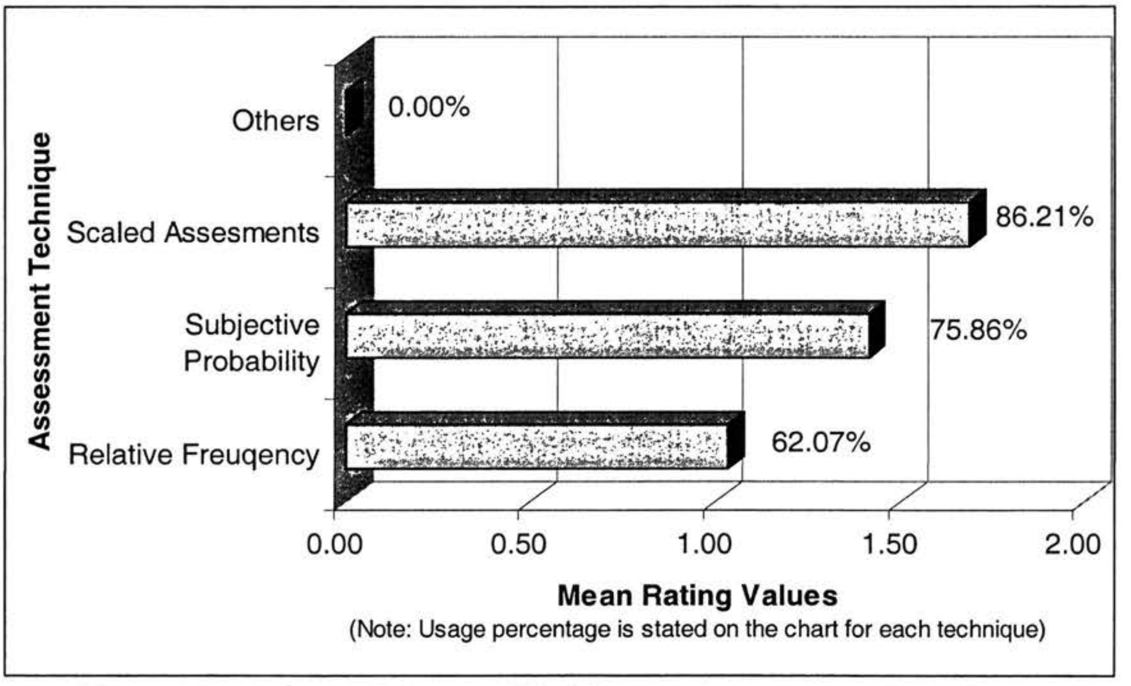

Figure 5.1.14: Overall Usage of Risk Impact Assessment Techniques

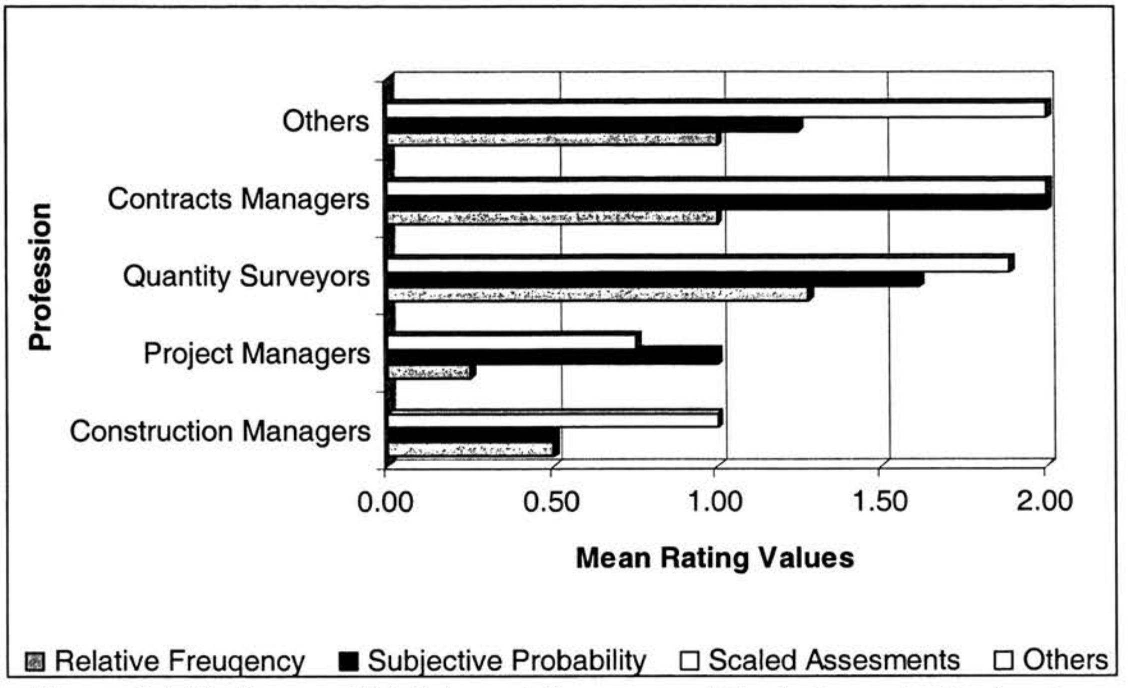

Figure 5.1.15: Usage of Risk Impact Assessment Techniques by Profession

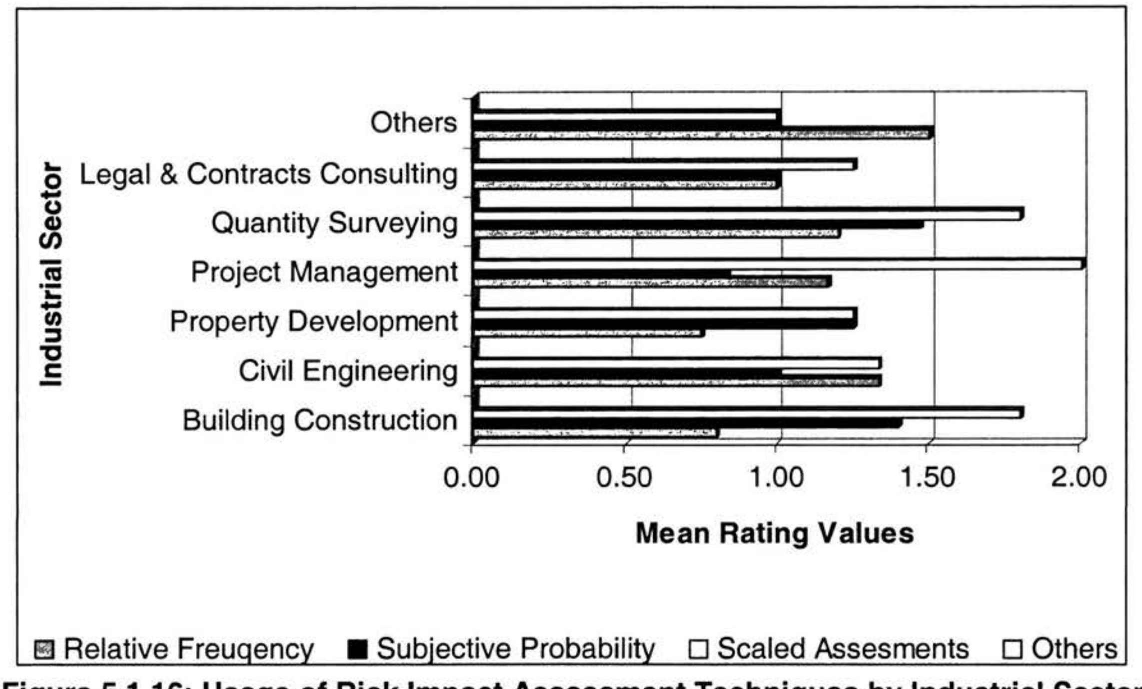

Figure 5.1.16: Usage of Risk Impact Assessment Techniques by Industrial Sector

5.1.5 Risk Analysis Techniques

Figures 5.1.17 to 5.1.19 summarise the results of this area. It is evident from the tables that risk analysis in the form that is applied in economic risk analysis is very much an unexplored area when it comes to contractual risk analysis. Generally, none of the techniques surveyed by the study is used to any significant degree. On average, probability analysis, sensitivity analysis, scenario analysis and ranking options are generally either never used or used only occasionally. It is also significant to note that most of the experts who use the probabilistic techniques were from comparatively smaller companies with annual turnovers of less than £5 million, and that no other methods of risk analysis are used by any of the respondents. At first sight, the results appear to contradict the findings of Simister (1994) in whose study about 72% and 60% of respondents indicated that they currently used Monte Carlo simulation and sensitivity analysis respectively. However, Simister's study merely reported how many of the surveyed participants currently use the techniques but did not investigate how frequently they use them. The majority of the 72% that used Monte Carlo simulation according to Simister's study could well be occasional users of the probabilistic approach. The present study does not only measure the numbers of participants who use the various approaches, but also how frequently the actually use the different approaches.

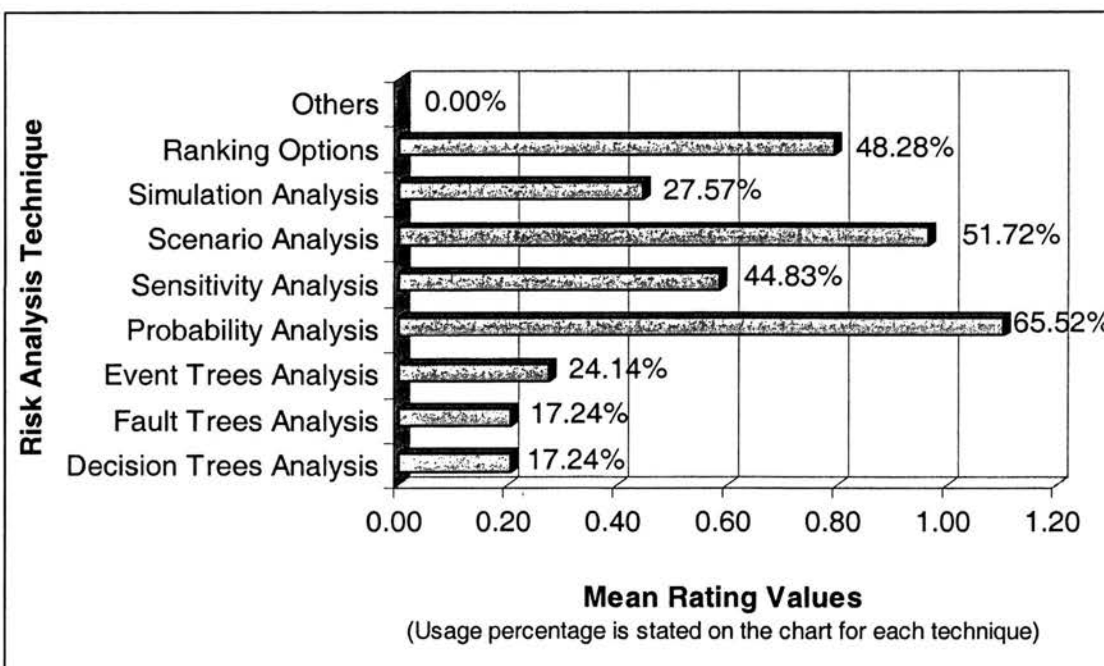

Figure 5.1.17: Overall Usage of Risk Analysis Techniques

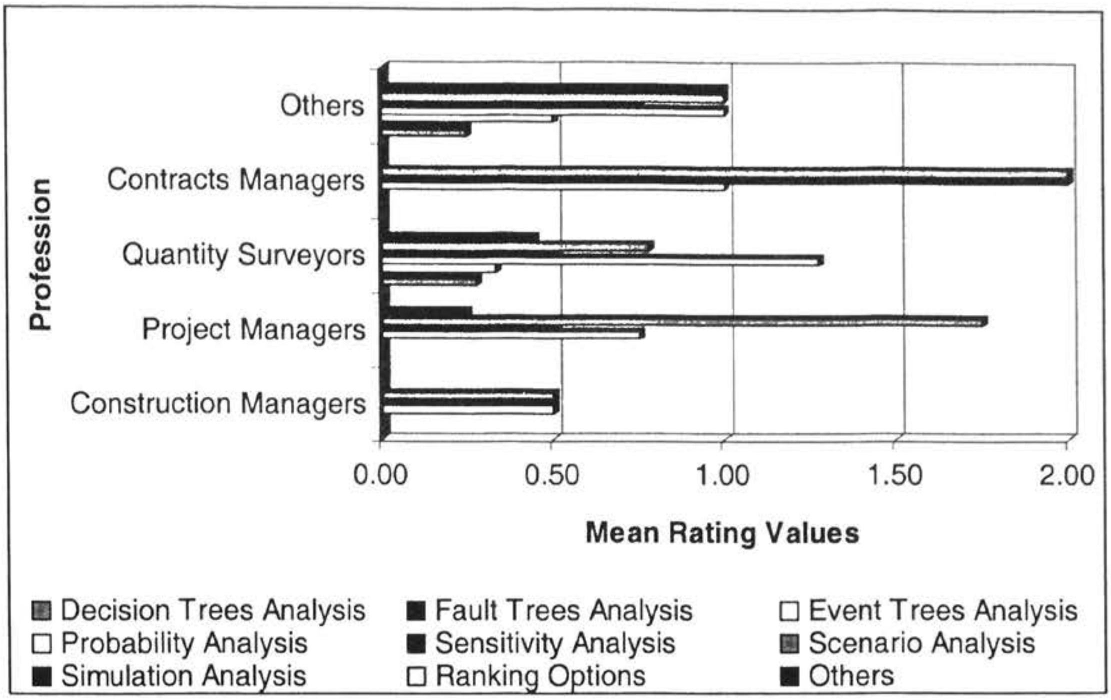

Figure 5.1.18: Usage of Risk Analysis Techniques by Profession

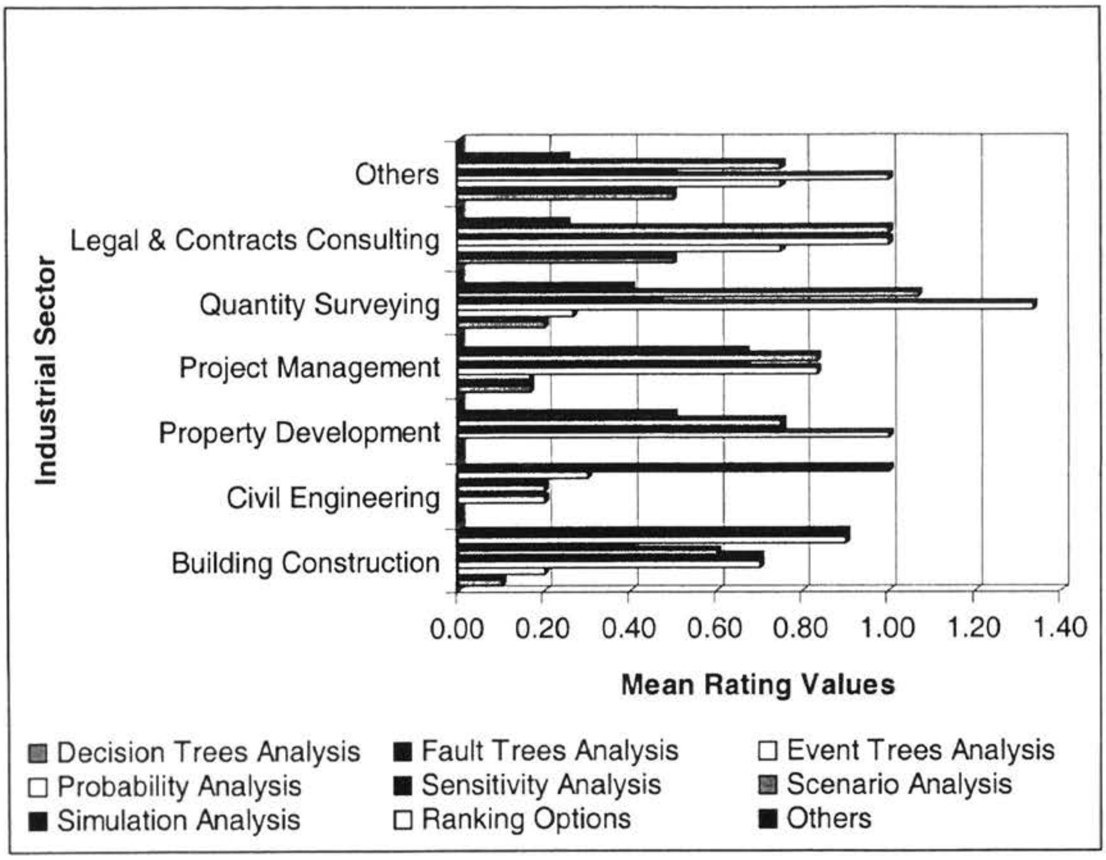

Figure 5.1.19: Usage of Risk Analysis Techniques by Industrial Sector

These results are consistent with the findings presented in the previous section on risk assessment techniques. It is also interesting to note however, that even though scaling methods and subjective probability assessments are the techniques used most frequently for evaluation risk likelihood and impact, they are only used occasionally when making final analytical decisions about the risks. This suggests that the estimates that are derived for risk likelihood and impact are often single point estimates and not of the type that can be used in a rigorous probabilistic analysis such as Monte Carlo simulation. It appears that although management systems are becoming more reliable and efficient and construction project environments more complex, not much effort is being made by the industry to incorporate available and adaptable systems into its risk management practices.

5.1.6 Testing the Hypotheses

It should be recalled that this part of the study revolved around two related operational assertions or hypotheses stated in chapter 4, that:

(a) there is very little application, if any, of systematic and rigorous probabilistic methods to contractual risk in construction;

(b) analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques.

Hypothesis (i) is considered as supported if the majority of the participants use it "less-than-frequently". Thus, on the rating scale of 0 to 4 explained in section 5.1, a mean rating value of less than "2" (which represents "frequent" use) would indicate a support for the hypothesis. Chapter 2 discussed the various risk identification and analytical techniques and their capacity to deal with the effect of perception on the subjective estimates used in risk analysis. Hypothesis (ii) is thus considered as supported if the majority of the participants frequently use those techniques that do not adequately deal with the effect of perception on the subjective estimates, or if they use techniques that adequately deal with the effect of perception on the subjective estimates "less-than-frequently". Thus, on the rating scale of 0 to 4 explained in section 5.1, a mean rating value of more than "2" (which represents "frequent" use) for the first set of techniques, less than "2" for the techniques that deal with perception would indicate a support for the hypothesis (ii). Table 5.1.4 presents a listing all the risk management techniques evaluated in this study ranked in the order of their overall mean rating values.

Table 5.1.4: Ranking of Mean Rating Values of Risk Management Techniques

Risk Management Technique	Mean Rating Value
Risk Identification	
Synectics	0.45
Expert interviews	0.69
Risk records	1.00
Prompt lists	1.76
Brainstorming	1.90
Checklists	2.21
Pondering	2.97
Risk Likelihood	
Relative Frequency	0.86
Scaled Assessments	1.76
Subjective Probability	1.79
Risk Impact	
Relative Frequency	1.03
Subjective Probability	1.41
Scaled Assessments	1.69
Risk Analysis	
Decision Trees Analysis	0.21
Fault Trees Analysis	0.21
Event Trees Analysis	0.28
Simulation Analysis	0.45
Sensitivity Analysis	0.59
Ranking Options	0.79
Scenario Analysis	0.97
Probability Analysis	1.10

(a) Testing of Hypothesis (i)

For risk Identification, the only techniques with mean ranking values of more than "2" are Pondering and Checklists. Synectics and Expert interviews that have the highest potential for generating the broadest listing of risks have mean rating values of less than one, indicating that at best, they are only used occasionally. The mean rating values for risk likelihood, risk impact and risk analysis techniques are all less than "2". It is worth also noting that these techniques (including the risk identification techniques) are generally used within an In-house individual assessment setting. The survey results thus support hypothesis (i).

(b) Testing of Hypothesis (ii)

From Chapters 2 and 3, the only contractual risk management techniques that can adequately dealing with individual perceptions and biases are Subjective Probability estimates derived within a group setting (Synectics or In-house Multidisciplinary Group) and probability analysis including Simulation analysis. The mean rating values for these techniques are all less than 2. Furthermore, they are also generally used within an In-house individual assessment setting. These results thus supports hypothesis (ii).

It is evident from these results that there is a significant gap between the techniques available to the construction industry and what are actually used in the management of contractual risks. Contractual risks by their nature make it highly unlikely that one individual will have sufficient first hand experience of each risk to enable him/her conduct accurate identification and analysis of such risks in any major construction project, without making the whole risk management exercise heavily subject to the errors caused by personal biases and perceptions. This is supported by the fact that although 160 professionals were selected based on at least 10 years of industrial experience to participate in the study, only 29 felt they had sufficient experience to enable them respond to the survey questions. Yet the predominant practices in the industry seem to centre on one individual dealing with risk management. The practices do not adequately take account of the nature of contractual risks nor help to make risks explicit. Perhaps, these practices account for the excessive claims and litigious disputes in construction (Murdoch & Hughes, 1992).

The economic practicality of bringing together a team of experts for risk analysis on small projects is undoubtedly questionable, but it is possible to employ available computing and information technology or consultative approaches (e.g. expert interviews) in overcoming the disadvantages of the individual expert assessment approach. This appears not to be the case in the industry generally. Very few professionals use risk analysis techniques such as probability analysis, sensitivity analysis and scenario analysis. Those who use them appear to do so only occasionally. There is use of scaled and subjective judgmental probability assessments techniques to various degrees, but very little application is made of these assessments as input variables for a formal, systematic probabilistic analysis and quantification of the risks. Further interviews with some of the experts suggest the perception that such a formalised process is perhaps only within the resource capabilities of the very large construction firms. This perception is not supported by the findings of the research. On the contrary, the majority (about 68%) of companies using all the various kinds of risk management techniques have a turnover of less than £5 million. In fact, companies with turnover of under £1 million who use the various techniques account for over 40% of the respondents. The author is thus of the view that the use of formalised processes for risk management is not, and need not only be within the resource capabilities of the very large construction firms given advances in modern technology and evidence from this research and from other industries. Most of the techniques surveyed are used on a regular basis by other industries that are prone to similar risk as those faced by the construction industry, and are considered generally beneficial to the risk management effort.

5.1.7 An Overview of Risk Management Practices in Ghana

Table 5.1.5 presents a breakdown of the 54 experts who were selected (see sections 4.3(b) and 4.4.2) and interviewed and their effective participation is broken down as follows:

Table 5.1.5: Profiles of Ghana Survey samples

Category		***Number Targeted***	***Participants***	***Response Rate***
Consulting Quantity Surveyors		29	27	93%
Construction Experts	Class 1	16	11	80%
	Class 2	9	9	100%
Total		54	47	87%

5.1.7.(a) Techniques for assessing risks at the pre-construction stage

The objective here was to find out who are responsible for risk management within the organisation and how the risk identification process is structured (whether in-house individual, in-house Synectic team, in-house multidisciplinary team or an external organisation), and how risks were identified and analysed at the pre-construction stage.

Approaches to Risk Identification

Within the firms of all the 27 consulting experts interviewed, the approach was for the risk identification process to be handled by the in-house senior surveyor/partner (sometimes assisted by a junior Quantity Surveyor) who also had full responsibility for the project. The nine Class 2 contractors relied on external Quantity Surveyors for all their pricing and tendering needs, including any pre-construction risk assessment. In three of the foreign (Class 1) contracting firms, risk Identification was handled jointly by the Estimating Managers and the Insurance Managers. The remaining 8 Class 1 contractors had in-house quantity surveyors who were responsible for risk assessment and pricing, but the approach to risk identification and assessment was similar to those employed by the consulting Quantity Surveyors (single individual sometimes assisted by a junior Quantity Surveyor).

Techniques for Risk Identification

Among the twenty-seven Consulting firms and the eight Class 1 Local contractors, Pondering and checklists were the standard techniques used for risk identification. The checklists often consisted only of risk items highlighted by the standard contract forms. It was, however, not normal practice to conduct risk identification on a project-by-project basis. These same techniques were employed for the nine Class 2 contractors. Pondering and checklists were also the techniques used for risk identification in the three foreign firms where risk assessment was handled jointly by the Estimating Managers and the Insurance Managers. Three foreign experts from foreign companies claimed they had a system for removing every uncertainty in the project and pricing every risk in the contract, but would not discuss how their system operated.

Techniques for Quantifying Risks

Although the likelihood and impact of risks are considered during the pricing stage, there were no usages of any of the standard techniques for quantifying the likelihood or impacts of the risks or for pricing the risks into the estimates for the project discussed above. It was the general belief among those interviewed that doing so may price their clients out of the competition. Instead, a percentage contingency sum is allowed for in the contract to cover economic risks and an allowance is made in the contractor's profit mark-up for all other risks. Insurance was normally recommended for any specific risks that could not be catered for by the general project insurance. These practices were true of both the Consulting firms and the seventeen local construction companies. Among the three foreign firms mentioned above, familiar economic and contractual risks were dealt with as above, but other risks identified by either of the managers were discussed, insurance premiums requested for the risks, and the matter brought to the attention of the client and included as a separate item in the contract.

5.1.7.(b) Risks handling during project execution

Methods for dealing with economics risks

Until recently, economic risks such as fluctuations and variations in construction work under the international contracts were dealt with using the FIDIC Price Adjustment Formula detailed in the standard FIDIC Form of Contract. However, the Building and Road Research Institute of Ghana (BRRI) has, through research based on data from Ghana develop a Ghanaian-specific adjustment formula and tender price indices for both pre-tender pricing and fluctuations during project execution. The formula for the Price Adjustment Factor p , is generally given as:

$$p = x + a\frac{EL}{EL_o} + b\frac{LL}{LL_o} + c\frac{PL}{PL_o} + d\frac{FU}{FU_o} + e\frac{CE}{CE_o} + f\frac{RS}{RS_o} + g\frac{TI}{TI_o} + h\frac{MT}{MTo}$$

where x is a fixed coefficient representing a non-adjustable portion in contractual payments; a, b, c, d, e, f, g and h are weightings (coefficients) representing the estimated portion of each cost element (labour, plant, materials and other inputs to the works) in relation to the estimate of the cost of the works (net of Provisional Sums, and $EL, LL, PL, FU, CE, RS, TI$ and MT are the official current cost indices or prices applicable respectively to Expatriate Labour, Local Labour, Construction Plant (provision and maintenance), Fuel, Cement, Reinforcing Steel, Timber, and Marine Transport and

Miscellaneous expenditure at the time prior to the date of submission of the payment under certification for adjustment, and $EL_o, LL_o, PL_o, FU_o, CE_o, RS_o, TI_o$ and MT are the base cost indices or prices corresponding to $EL, LL, PL,$ etc., at the time prior to the date of submission of bids. Variations occurring within the contract period are generally dealt with by negotiation between the contractor's Quantity Surveyor and the Client's Quantity Surveyor in accordance with the rates agreed in the bill of quantities. However, it is very common among government-funded projects for a project to be delayed by as high as 100-500% thereby making the rates contained in the original Bills of Quantities inappropriate to use for the valuation of variations. All work (including variations) done outside the original contract period are therefore paid for in accordance with current rates prepared by the government's Quantity Surveyors (usually the Architectural & Engineering Services Corporation (AESC) but sometimes one of the local Consulting firms) that are current for the period during which the work was done.

Methods for dealing with contractual risks

Project completion delays caused by client: The approaches employed in Ghana differed from one category of contractor to the other. Three primary approaches emerged from the survey:

(a) *Foreign Contractors*: Generally, such contractors followed the terms of the contract strictly and officially terminated the contract in the event of such a default on the part of the government/client. They would then claim any amounts due them and any further amounts necessary to get them to re-start the work. However, those interviewed were unwilling to divulge any information on the extent of any such delays or the impact of project cost or their profit.

(b) *Local Class 1 Contractors*: Contractors in this category would generally not formally terminate the contract, but would move all their plant, equipment and labour out of the site and leave only a skeleton security staff. They would continue to have progress meetings with the Client's representatives at the project site until such a time that effective work can be re-started on the site. Claims made for such default are often a subject of negotiation between the Client's representatives and the contractor.

(c) *Local Class 2 contractors*: although the approach by this category of contractors is essentially the same as (b) above, most of the contractors are often unable to start work again on the sites once they move their limited resources on to other projects. This often leads eventual to complete abandonment of the site. Cognisant of their lack of recourse to the law in case of the default of the client, such contractors will often "front-load" their estimates and thereby get paid most if not all of their projected profit on the project during the very early stages of the project. In this way, any default by the client that leads to eventual abandonment would not result in any losses on their part. The downside of this is that with most of the finance for the project having been paid to a contractor who has been given cause to leave the site, the projects often remain uncompleted.

Delays in payment by client: The approaches employed in handling this also differed from one category of contractor to the other. The three primary approaches emerging from the survey and a fourth approach proposed by the BRRI are described below:

(a) *Foreign contractors*: Foreign contractors strictly follow the terms of the contract and claim interest on any overdue payment. A complication arises where the Ghana government and an external body such as the IMF jointly fund the project (usually at a 20:80 ratio). Claims for the completed works are thus broken down into a claim for a foreign currency component (submitted to the IMF) and a claim for the local currency component (submitted to the Ghana government). In the past, payment of the IMF component of the claim was made conditional upon payment by the Ghana government of the local currency component of the claim. Payment delays on the part of the government were therefore stifling progress on the project. In recent times, this condition by the IMF and other external bodies has been removed. Work thus continues on project in spite of any payment delays on the part of the government, while the contractors claim for interest payment continue to accrue even further interest. Sometimes this leads the two parties into litigation.

(b) *Local Class 1 Contractors*: two approaches were identified among this category of contractors. The first is essentially the same as described in (a) above. Some of the well-established foreign companies in this category however employed a second approach. Using payment-default history that they had built up on the Ghana government, they would first estimate the most likely duration of payment delay that would happen at the most sensitive period of the project (in terms of contractor's cash flow management). Based on their expectation of the value of the claim at that time, they would calculate the interest that would be due on the claim in view of the anticipated delay and add this value as a hidden item to the amount to be required from the Ghana government as part of the Project Mobilisation Fund before work could start on the site. This approach seems to work well for the contractors, as it avoids litigation without the contractor losing out financially. This approach is tantamount to asking the client to pay a risk premium for the risk of payment delays, since the money collected as part of the Project Mobilisation Fund is never returned to the government even if there is not payment delay.

(c) *Local Class 2 Contractors*: The Ghana government tends to be the main source of contracts for these contractors. Contractors in this category therefore hardly claim any compensation for payment defaults by the government for fear of being blacklisted by the government's representatives. On some occasions, they would negotiate with the government's representatives to arrive at some form of compensation, but this is often even at the instigation of the government's Quantity Surveyors. The result of this again is that where the contractor is unable to sustain the project financially in spite of the delay, the company either goes bankrupt or abandons the project.

In recent times, an understanding of the way in which the government pays for construction projects is making both contractors and government Quantity Surveyors to resort to the preparation of Advance Interim Payment Certificates to ensure funds for payment are available by the time the work is actually done. The government's programme for all work to be undertaken in any given year is given in the Public Investment Programme (PIP), which is announced as part of the national budget at the beginning of the year. The amounts to be spent by the government on all on-going construction projects are indicated in the years PIP. Contractors therefore prepare monthly interim Payment Certificates (for work anticipated to be completed by those months) and to the total value of the amount specified in the PIP for their particular project and submit these on a monthly basis to the Government Quantity Surveyors for approval and payment, months in advance of any work being done. The logic of this approach is that by the time the payment delay process runs its course and the government is ready to make any monthly payment, that the contractor would have duly completed work. The risks to the government and the legal complications that this approach poses are very obvious.

(d) *The formation of a Contractors' Bank*: The BRRI has proposed to Ghanaian contractors the formation of a contractors' bank funded and owned by contractors with the purpose of providing a formidable front for contractors in dealing with the contractual problems they face, particularly in dealing with the Ghana government who is their main employer.

Under this proposal, only contractors would contribute share capital in the formation of the Bank, which will function as a development rather than a commercial bank. On winning projects, Contractors can then obtain the necessary guarantees and funding from the Bank which they will nominate as their (contractors') agents. All member-contractors' claims to the government for interim payments will be handled by the bank, which will immediately pay a proportion of the claim to the contractors concerned to enable them to continue their projects. The balance of the claim will be made once the bank has obtained payment from the government. Then, on a monthly basis, the bank will make one claim from the government for all the individual claims submitted by their member-contractors, follow-up on the claims and charge any due interests to the government until the claim has been honoured. The BRRI argues that this system offer three major advantages to the contractors:

(i) Since the Bank will be in implied contractual relationship with the government and claims by a number of contractors will be handled as one claim by the Bank, no contractor will become a subject of blacklisting by the government. In addition, it is impossible for the government to blacklist all the member-contractors of the bank and get away with it.

(ii) Contractors can obtain cheaper financing, guarantees and sound professional assistance for their projects, compared to what they will get through the commercial banks.

(iii) Contractors, acting through the bank, can become a formidable force for ensuring that changes in government policies and practices necessary for ensuring improvements in the performance and productivity of the industry are implemented.

5.1.7.(c) Causes/sources of project and payment delays by client

Political Factors

In order to appear to be doing well during their term of political office, the ruling government often adopts a policy of starting a number of construction projects (particularly road construction) every year that budgetary constraints clearly indicate that they would be unable to complete. Uncompleted projects are then often blamed on the incompetence of contractors who are often not entirely guiltless. In their desire to stay in business, a number of contractors use various means to win projects for which they are not very well equipped. The result is that while new projects are started every year, older projects become abandoned often for as long as 3-5 years!

Economic Factors

Payments of the local currency components of claims are paid from revenues generated locally by the Inland Revenue Services (IRS). The poor tax collection systems and performance of the IRS often results in funds not being available when they are planned to be ready for honouring projected government expenditure. Thus, claims often have to wait until funds become available for their payment. In the government's bid to reduce delays especially on major international projects, it often relied on borrowing from the funds of the Social Security & National Insurance Trust (SSNIT) which holds the social surety funds of Ghanaian workers. However, the commercialisation of the operations of SSNIT in recent times that led it into very successful real estate and a rather extremely unsuccessful speculative office development has resulted in SSNIT no longer having the surplus funds to bail the government out on a regular basis.

Foreign Loan/Grant Conditions

A third factor relates to the manner in which certain external funds (e.g. aids/grants from donor countries) are given. It is often the requirement of such grants/aids that the money is used to purchase goods or services from the donor country. Such conditions imply that although contracts for projects may have already been signed commencement of work on site can often not proceed until the goods or services have been sold in Ghana!

Legal Factors (Land Litigation)

The land ownership system in Ghana is very complicated and land very easily becomes a subject for serious legal battles not only for individuals and real estate developers, but also for the government. Although the government owns several tracts of lands in Ghana, most of the lands in Ghana are "Stool Lands" owned by traditional chiefs on behalf of their clans. Often, some of these stool lands are given to members of the clans for their personal ownership. These can either be developed by these members or sold on to other interested parties. The lack of proper documentation of such transfers in the past has lead to current situations where it is possible for multiple persons to claim competing ownership of the same piece of land at ant one time. Anyone wanting to develop any area involving that piece of land will therefore have to first resolve the issue of ownership (often through the courts) and then negotiate appropriate compensation/payment for the land with the rightful owner(s) before any development can start on the site. This can be a lengthy process, and in the absence of any effective means of tracking down stakeholders in the land, the only option often left for developers (including the government) to pursue is to start work on the site and thereby attract the attention of the stakeholders. This always starts a litigation process, which immediately calls for a suspension of the project works!

Cultural Factors (Work Ethics)

One of the legacies of the colonial administration in Ghana is a work culture that entrust too much power to the person at the top and makes subordinates unreasonably unwilling to make binding decisions in the absence of "the boss", often to a point where no work gets done without a direct instruction from "the boss". One abuse of this totalitarian culture is that workers who are in charge of dealing with contractors' claims often use the absence of "the boss" to deliberately frustrate contractors in order to attract a tip. This requirement for tips, especially within the government ministries is so well known that the majority of contractors and consultants in Ghana (including foreign firms) build the tips for the government staff into their estimates!

5.2 Developing a model for eliciting quantified opinions about contractual risks

One of the objectives of the research was to develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception, and provides these opinions as an input variable to the systematic and effective analysis of contractual risk. As stated in section 4.2.3, achieving this objective required

(a) applying similar techniques and processes used for eliciting quantified expert opinions for economic risks analysis, to comparable contractual risk to establish suitability for generating similar estimates from construction experts.
(b) developing the quantified opinions into probability estimates that can be used as input variables for the subjective probability analysis of contractual risks.

These key tasks involved four sub-activities in practice:

(i) Developing the model for eliciting subjective probabilities of contractual risks
(ii) Testing and refining the model through the analysis of the test results
(iii) Elicitation of subjective estimates from the UK and Ghana using the Final model
(iv) Developing elicited estimates into prior probabilities for Bayesian analysis.

The development, testing and refinement of the elicitation model (sub-activities (i) and (ii)) were done as part of the pilot survey and presented in rest of this section. The application of the refined model (sub-activities (iii) and (iv)) was done as part of the Main surveys conducted in the UK and Ghana and is presented as part of section 5.3.

5.2.1 Eliciting subjective probabilities of contractual risks: The initial model

This part of the study relied heavily on existing published work, including the works of Chelsey (1975), Spetzler & Staël Von Holstein (1975), Chapman & Ward (1997) and Vick (2002), and the initial model developed for eliciting subjective estimates of contractual risks was the result of the analysis of the extensive literature review presented under the appropriate sections of Chapters 1 to 4. The outline of the model which describes the process and methods used for eliciting subjective estimates during the Pilot Study is summarised in Table 5.2.1 below.

Table 5.2.1: A model for eliciting subjective probabilities of contractual risks

Phase	Purpose(s)	Process Steps
Preliminaries	**Prepare for Process**	• Confirm need for Elicitation exercise • Appoint, brief and train Probability Assessor/Facilitator • Establish Elicitation Objectives and Approach • Establish Process budget for time, cost and human resources
	Define the risk Problem	• Confirm project definition • Clarify uncertainty and clearly define risk(s) for which prior estimates are being sought • Decompose risks and define decomposed risks if necessary • Obtain sample evidence for risk(s)
	Develop Elicitation/Assessment Schedule/Questions	• Define questions using the relative likelihood' and Direct Response methods • Define questions using a continuous variable scaling technique and Direct Response methods
	Expert Selection	• Determine appropriate professional categories • Determine appropriate industrial sector of expertise • Determine Extent of relevant professional expertise • Establish target expert group • Obtain actual experts through prequalification

Table 5.2.1: (*Continued*)

Phase	Purpose(s)	Process Steps
Expert Elicitation	**Set up appointments for elicitation/mail Assessment Schedule**	• Introduce the Assessor/Facilitator • Explain the purpose of the elicitation • Leave the elicitation schedule or arrange an appointment for the elicitation interview • Discuss Feedback processes and their possible further involvement in the process.
	Have Experts formulate and encode their estimates	• *Motivating* the subject by establishing rapport and investigating the subject's biases. • *Structuring* the uncertain quantity by having it clearly defined and explained to the expert. • *Conditioning* the subject by making the subject think fundamentally about his judgement and to avoid any of his cognitive biases. • *Encoding* or quantifying the probability judgements, and • *Verifying* the responses by checking for consistency and seeing if the subject believes his results.
Analysis of Subjective Judgements	**Assign numerical probability values to expert judgements**	• Obtain estimates of full range of risk attributes through smoothing and scaling of expert estimates • Convert smoothed estimates into coherent probabilities that sum up to unity • Map and define probability distribution
	Assign numerical probability values to aggregate values of elicited judgement	• Define appropriate weighting for aggregation of estimates • Aggregate estimates using selected weighting • Obtain estimates of full range of risk attributes through smoothing and scaling of aggregated estimates • Convert smoothed estimates into coherent probabilities that sum up to unity • Map and define probability distribution

The above represents an idealised view of the approach which might be implemented by a corporation with sufficient resources. Obviously doctoral research is more limited in resources and it is not always possible to fully implement the approach. The goal is different from the corporate setting. There is a need to determine by the 'pilot' study whether the approach is likely to be successful and determine whether the approach can be made more successful by adaptation. In such circumstances it is desirable to be more flexible with the approach to examine these questions. Hence the current study does not directly implement the above but takes elements to explore how they function in a cross cultural study.

5.2.2 The relative likelihood method

As indicated in section 4.3.2(c), the survey adopted the "relative likelihood" method (Moore & Thomas, 1976; Chapman & Ward, 1997) and aimed at eliciting direct estimates of probabilities (associated with the occurrence of payment delays in an international project described by a vignette) that would form the extremes of the probability distribution, and also the key intermediate values of the subjective prior probability distribution. The "relative likelihood" or "relative heights" method used in this part of the research consisted of four stages. First, estimates from the expert regarding the risk variable in question are elicited in the following manner:

(i) the minimum value of the risk variable, representing the lowest value that is either the least likely or most unlikely value that the variable can assume

(ii) the maximum value of the risk variable representing the highest value that is either the least likely or almost unlikely value that the variable can assume

(iii) the most likely value of the risk variable representing the modal value relative to which other key intermediate values the risks can be assessed

(iv) the modal value is assigned a likelihood rating or units that represent the highest possible rating (say this rating is 60 units or "*A*")

Key intermediate values the risk variable which would represent the key intermediate points of the probability distribution for the risk are then obtained by eliciting

(v) a value for the risk greater than the modal value that is half as likely to occur as the modal value (i.e., that would have a likelihood rating of 30 units or ½A).

(vi) a value for the risk smaller than the modal value that is half also as likely to occur as the modal value (i.e., that would have a likelihood rating of 30 units or ½A).

(vii) a value for the risk greater than the modal value that is a quarter as likely to occur as the modal value (i.e. a likelihood rating of 15 units or ¼A).

(viii) a value for the risk smaller than the modal value that is quarter also as likely to occur as the modal value (i.e. a likelihood rating of 15 units or ¼A).

Unlike the approach described by Moore & Thomas, (1976), the minimum and maximum values of the variable are elicited first to avoid the effects of central bias on the elicited values. This approach also ensures the display of sufficient spread in the distribution for the risk variable (Ranasinghe and Russell, 1993). Table 5.2.2 for example, gives the group/aggregate estimates of the mean values regarding two attributes (likelihood and impact) of the risk of payment delays in an international construction project in Ghana, from construction experts from the UK and Ghana.

Table 5.2.2: PDF Measures of Means of Estimates of the Risk of Payment Delays

PDF Measure of Risk	**Rating**	**Mean Values of Relative Estimates**			
		Risk Likelihood		Risk Impact	
		Ghana	UK	Ghana	UK
Minimum Number	-	23	29	15	23
Maximum Number	-	90	81	73	83
Most Likely Number ("A")	60	73	53	52	38
Higher Number Half as likely as "A"	30	79	66	55	52
Lower Number Half as likely as "A"	30	47	40	42	29
Higher Number a quarter as likely as "A"	15	84	74	63	58
Lower Number a quarter as likely as "A"	15	36	34	23	23

The second stage of the method involves the smoothing of the elicited estimates to "normalize" the data and obtain likelihood ratings for all the other possible values of the variable. The values elicited from the experts are plotted on a Scatter Diagram and a smooth curve drawn though the various points. The likelihood rating values of all the other possible values of the risk can now be obtained from the graph. Figure 5.2.1 for example represents the "smoothed' likelihood rating graph of the expert estimates from Table 5.2.2 regarding the occurrence of the risk of payment delays.

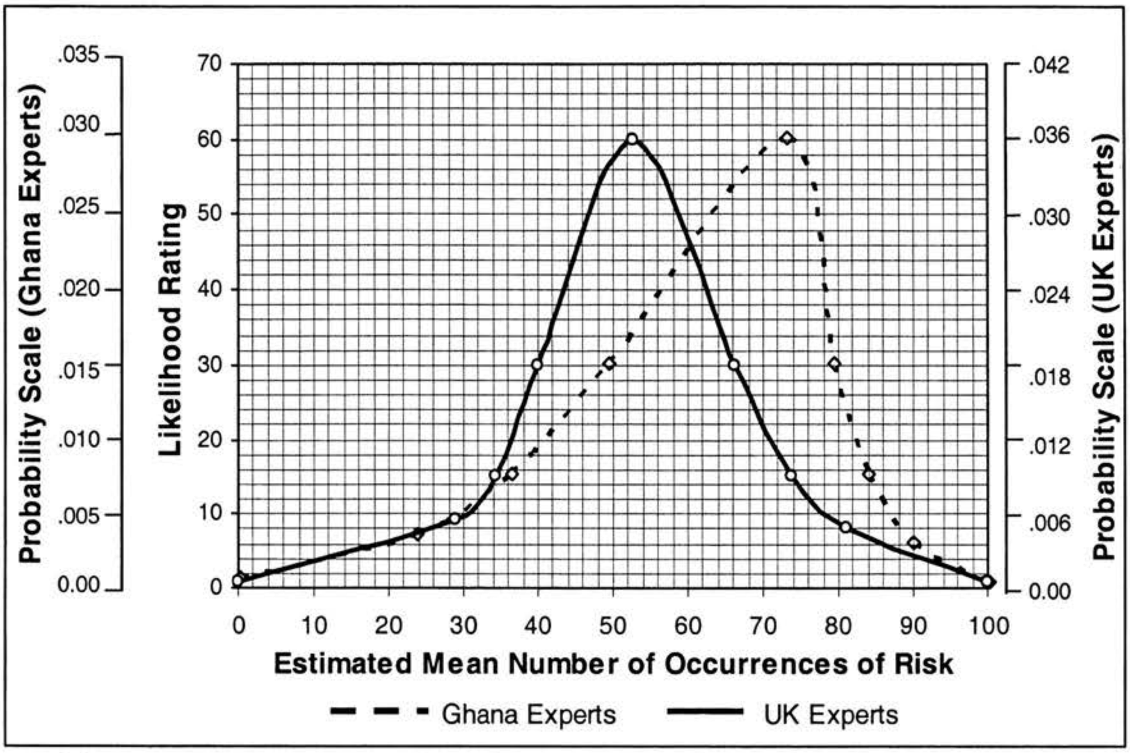

Figure 5.2.1: Estimates of the Occurrences of the Risk of Payment Delays

The third stage involves scaling of rating value each smooth value of the risk variable by the total of all the ratings to form probabilities that sum to unity. The minimum and maximum values of the risk need not have zero probabilities. Appendices 7 and 8 tabulate expert estimates, the smoothed values and the scaling of the smoothed values to obtain the associated probabilities for the occurrence of the risk of payment delays for experts from Ghana and the UK. In the final stage of the method, the probabilities are plotted to obtain the probability distribution of the smoothed estimates of the experts', which thus represent their belief functions. The smoothed curves in Figures 5.2.1 when read in conjuction with the probability scales for Ghana and UK experts also represent the PDFs and hence the belief functions of the UK and Ghana experts about the risk.

5.2.3 Testing and Refinement of Proposed Model

Data for this part of the study came from the UK-based Pilot study and sections 5.1 presented the survey sample and respondent characteristics of that survey. The analysis presented here is based on responses of experts to Section 5 of the Pilot Survey Schedule (Appendix 2) which was designed to test the elicitation model by eliciting subjective estimates that will help answer the question:

"What is the probability of encountering adverse ground conditions (a contractual risk) on a land that is mainly gravel?"

A detail description of the land which formed part of the vignette used for the schedule is given in the schedule. As can be seen in the schedule, the elicitation was based on two sets of questions that sought direct estimates of probabilities associated with the occurrence of adverse ground conditions among hundred typical projects described by the vignette. The first set of questions uses a 'relative likelihood' method described in section 5.2.2. The rationale for testing this approach was discussed in Section 4.3.2(c). Table 5.2.3 and Appendix 9 present the results of the relative likelihood approach (aggregated for the various categories of experts). Figure 5.2.2 presents the probability density functions based on the aggregated estimates. The method for developing the PDFs was also discussed in section 5.2.2.

Table 5.2.3: Direct estimates of the relative likelihoods of encountering Adverse Conditions by Profession

		Mean Values of Relative Estimates Per Profession					
PDF Measure of Risk	**Rating**	**Respondents' Aggregate**	**Construction Managers**	**Project Managers**	**Quantity Surveyors**	**Contracts Managers**	**Others**
Minimum Number	0	11.91	7.50	5.67	14.97	20.00	5.33
Maximum Number	0	37.86	37.50	29.00	41.60	42.00	30.00
Most Likely Number ("A")	60	23.04	17.50	14.00	25.94	30.00	20.75
Higher Number Half as likely as "A"	30	29.42	27.50	17.00	34.87	====	19.67
Lower Number Half as likely as "A"	30	16.96	15.00	8.75	20.00	25.00	11.25
Higher Number a quarter as likely as "A"	15	33.57	30.00	21.50	41.18	42.00	23.00
Lower Number a quarter as likely as "A"	15	13.81	7.50	5.67	16.59	22.00	11.25

(Note: ==== means no estimates were given)

A number of what appears to be inconsistencies in the estimates given by the respondents can be seen from the analyses, particularly with regard to tail estimates. For example, the average estimates from the Project Managers indicate a minimum possible value of 5.67, while an average relative likelihood rating of 15 units was also given to the occurrence value of 5.67 by the same group. A similar situation is true of Construction

Managers. The Contract Manager had difficulty estimating one of the mid-points of the distribution. These inconsistencies are perhaps confirmation of the difficulty encountered by construction professionals in estimating intermediate and tail values of a probability distribution, and the rather popular choice of the triangular distribution for most analytical work in construction estimating (Chapman & Ward, 1997). For the sake of comparison, the triangular distribution of the group aggregate based on the minimum, maximum and modal values of the Group Aggregate) is also given in Figure 5.2.2.

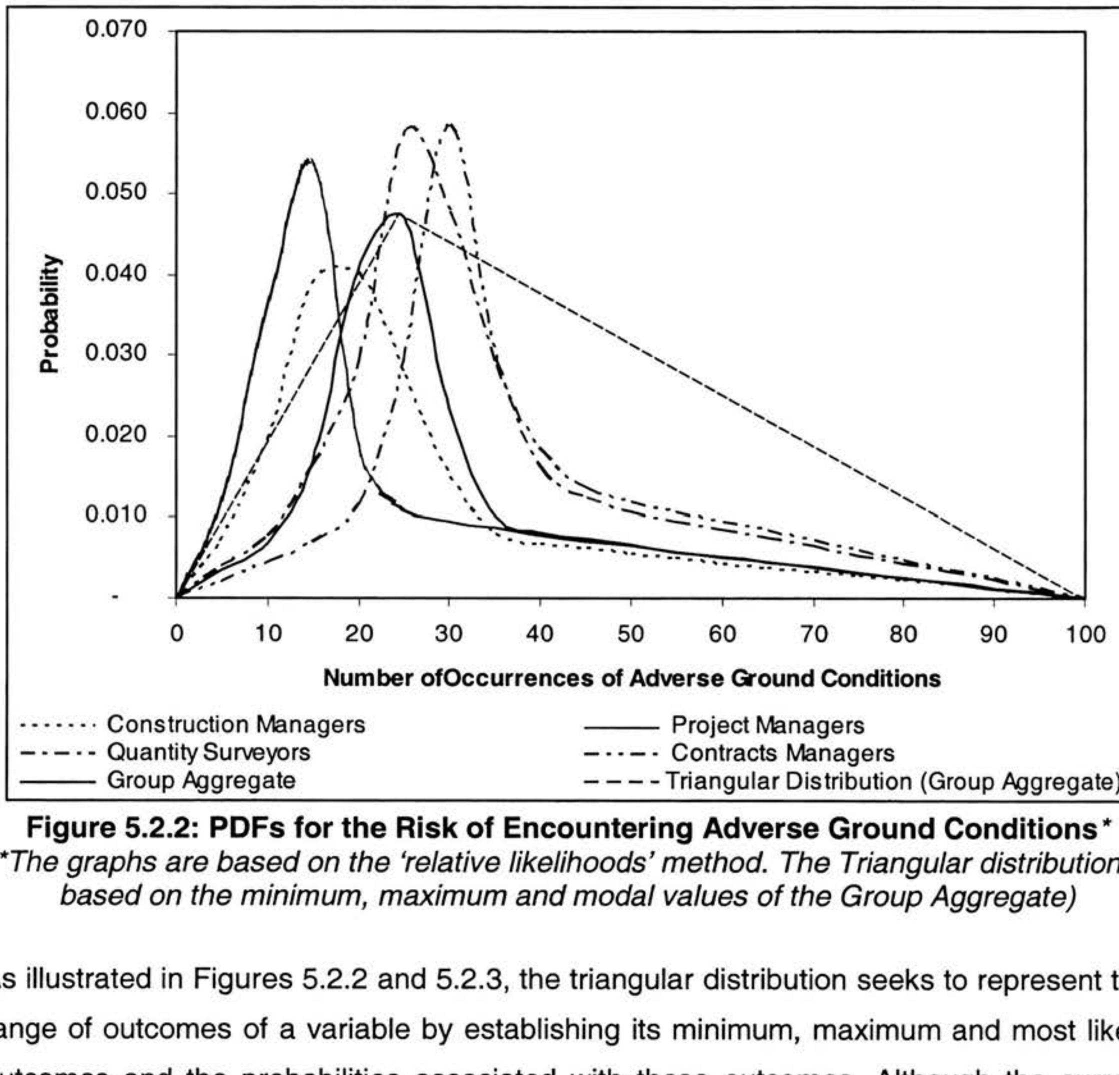

Figure 5.2.2: PDFs for the Risk of Encountering Adverse Ground Conditions*
*(*The graphs are based on the 'relative likelihoods' method. The Triangular distribution is based on the minimum, maximum and modal values of the Group Aggregate)*

As illustrated in Figures 5.2.2 and 5.2.3, the triangular distribution seeks to represent the range of outcomes of a variable by establishing its minimum, maximum and most likely outcomes and the probabilities associated with these outcomes. Although the current research results do not support the use of the triangular distribution for the analysis of all risks, the choice of the distribution has not been without reason. Rafery (1994) argues that in dealing with subjective definitions of probability, the distributions selected should be relatively easy to understand and have clear cut-off points since most estimators can say reasonably clearly that the cost or time for a particular variable will never exceed X_1

or be less than X_2. The present author contends that while these criteria for the choice of distributions are valid, it is equally important that the expert is given the opportunity to express his/her true beliefs as fully as possible without introducing any analyst biases by presupposing a form of distribution. Furthermore, as discussed in section 1.2(e), and demonstrated by this study, it is possible to elicit as much detail as possible about the distribution forms that represent the expert's true beliefs without the need for the expert having an advanced knowledge of Statistics. Also, contractual risks by nature can have zero values for occurrence.

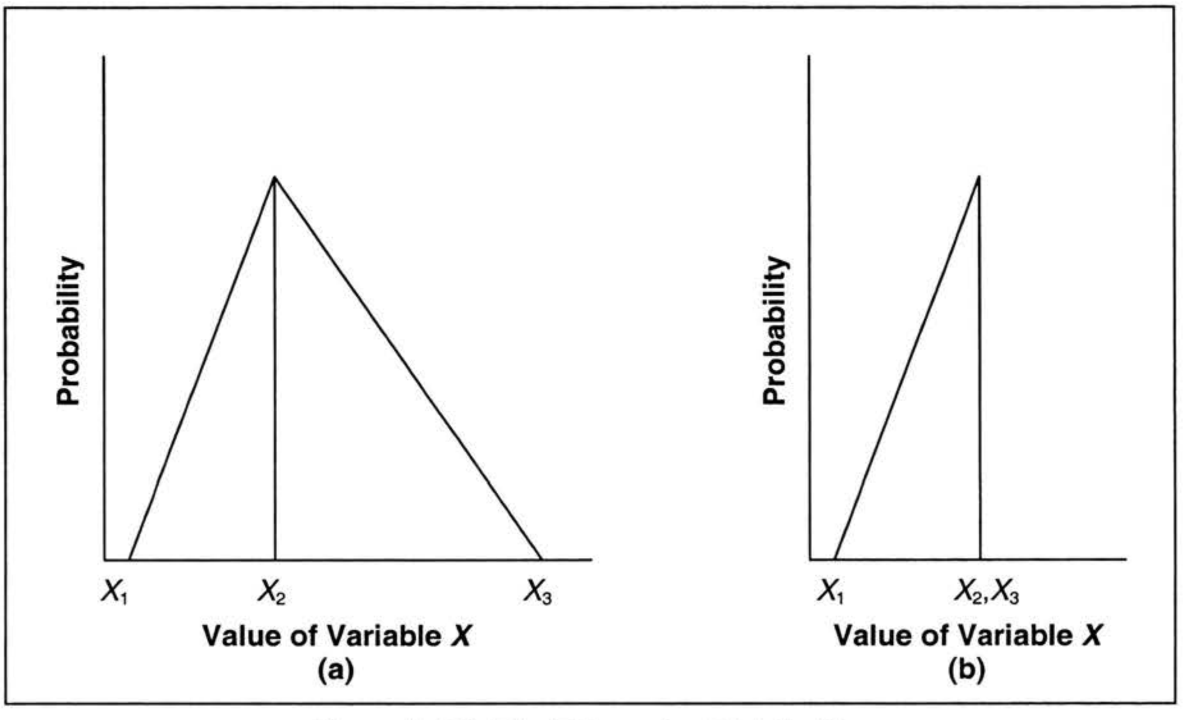

Figure 5.2.3: The Triangular Distribution
(X_1, X_2, and X_3 represent the minimum, most likely and maximum values respectively)

It is interesting to note from the research results that estimates from experts (such as property specialists) who did not belong to the four main categories were so inconsistent with each other that no meaningful distribution could be derived from these estimates. This can only confirm the importance of selecting "relevant" experts for the elicitation (section 4.4.2) and the fact that the estimates given by the experts from the main categories are genuine and that the inconsistencies shown in their estimates are not the result of guesswork, but rather that of genuine difficulty in providing probability estimates for tail values. It is also worth noting that the numbers of occurrences of adverse ground conditions given by all the experts fall within the range 3-42, providing an indication of the range of likely values to consider for preliminary decision making purposes.

Moreover, although the probability values given by the probability density functions from the various categories differ from each other, the shapes of the curves are fairly similar to each other. This indicates that the general problem representations for the risk among the experts are very similar, the differences arising perhaps because of differences in their experiences regarding the extremes of the occurrences. Thus, aggregation of expert opinions will capture a representation of the problem that truly reflects the collective knowledge and experience of the experts.

The second series of questions sought similar information using a continuous variable scaling technique (Section 5 Question 8 of Appendix 2). The aim was to act as a check on the consistency of the subjects responses, and to also evaluate the relative ease of understanding of the two questioning techniques in order to advise the refinement of the elicitation method for the final model. Table 5.2.4, Figure 5.2.4 and Appendix 10 present the results from this series of questions.

While the actual estimates and distributions from the two sets of questions display some inconsistencies, the distribution forms are evident and generally consistent throughout the professions. The results presented in Figure 5.2.2 are considered more accurate as the relative likelihood method is more efficient in reducing anchoring and other bias errors in the elicitation process (Ranasinghe and Russell, 1993). The scaling technique was therefore considered unsuitable as a questioning technique in the final model.

Table 5.2.4: Raw estimates of the likelihoods of encountering Adverse Conditions by Profession (using the Scaling Technique)

	Mean Values of Estimates Per Profession					
As many occurrences of adverse ground conditions as:	**Respondents' Aggregate**	**Construction Managers**	**Project Managers**	**Quantity Surveyors**	**Contracts Managers**	**Others**
0	12.96	12.50	2.67	15.13	1.00	33.50
5	57.17	27.50	88.00	49.71	88.00	32.67
25	42.88	57.00	47.00	39.40	35.00	36.00
50	20.79	18.50	24.33	32.13	19.00	10.00
75	8.87	6.00	8.00	18.00	6.00	6.33
95	5.93	3.50	3.67	20.47	1.00	1.00
100	3.95	0.00	0.33	18.40	1.00	0.00

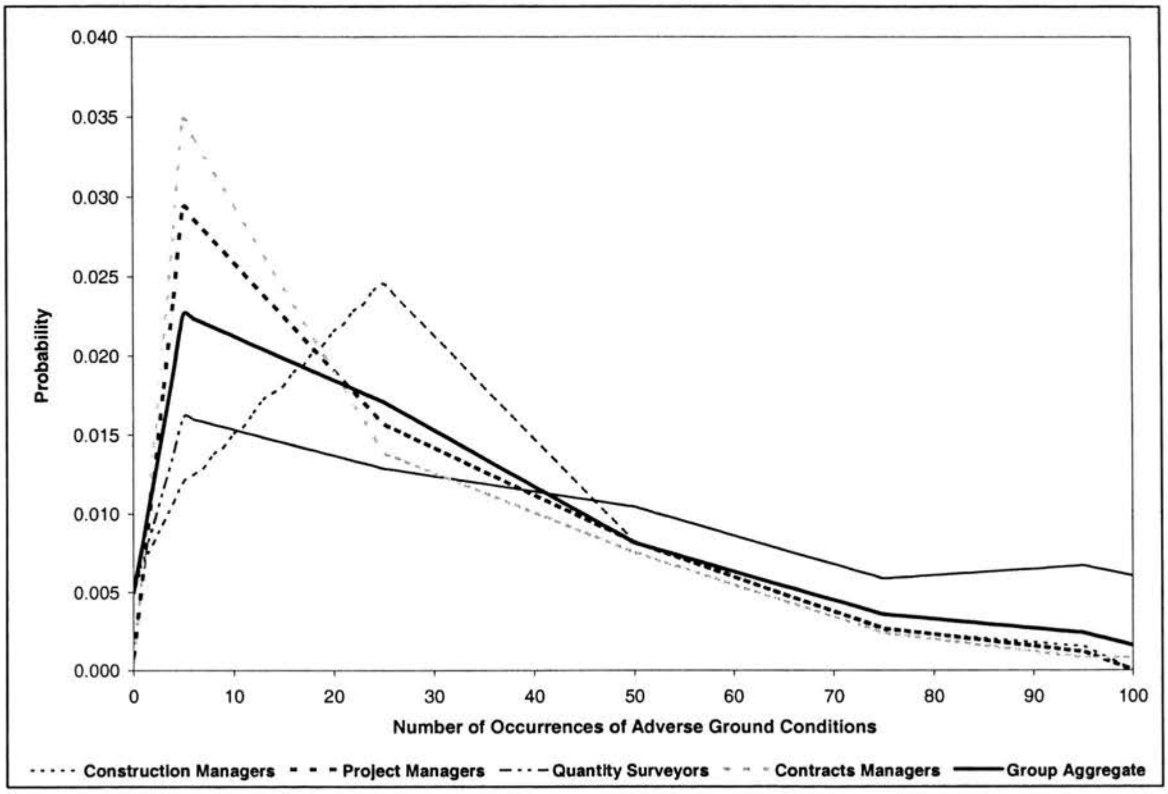

Figure 5.2.4: PDFs for the Risk of Encountering Adverse Ground Conditions (using the Scaling Technique)

The effective capturing of the problem representations of the experts by the elicitation model and the ability of the questioning and response methods to enable the experts to effectively self-elicit their beliefs and transform them into probability representations are very powerful confirmations of the effectiveness of the elicitation model used.

5.3 Risk perception and its impact on project performance

As discussed in Chapter one, the second objective of the research was to investigate risk perception in the construction industry and its impact on project performance. Project performance in construction is often measured using price or cost as a major yardstick. The argument posed by the research is that since estimates for risks form such a significant part of project costs (as much as 60%, according to Cullivan (1981)), any significant difference in risk estimates implies a significant difference in project price and hence project performance. As explained in section 4.2.2, this part of the research was designed to investigate risk perception in the construction industry, the impact of the socio-culture on risk perception and the influence of risk perception on estimates about risk and hence project performance. The underlying assertions were

(a) that differences in individual perceptions about risks will result in differences in their estimates about the same risks
(b) that differing socio-cultural backgrounds of risk experts will lead to significant differences in their estimates the same risks.

The data for this part of the study came from the Main surveys conducted in the UK and Ghana Survey, and a desk-study of construction accidents, injuries and incident investigation records and statistics of the Health & Safety Executive of the United Kingdom. As explained in earlier, although a similar desk-study and analysis was attempted for Ghana in order to provide a cross-cultural analysis of risk perception in construction, construction accident and incident recording systems in Ghana are almost non-existent. Three months of consistent efforts confirmed that no meaningful records of accidents existed at either corporate or national levels. Furthermore, most of the Ghana respondents had difficulty completing the questionnaire on risk perception. It was felt that no meaningful analyses could be made on the risk perception data from Ghana survey and that data was thus not analysed for this report (see section 4.3.(c)).

5.3.1 Characteristics of the Main Survey Respondents

As explained in section 4.4.2, the sample for the UK main study, consisted of 98 experts (comprising 24 from participants from consulting firms and 74 from contracting firms) while that of the Ghana survey consisted of 54 construction professionals made up of 25 experts from construction companies and 29 consulting Quantity Surveyors. The response rates for the various categories of experts are summarised in Table 5.3.1. The low response rate from the UK Construction firms was disappointing, although the quality of the eight responses was high and usable. The main reasons given for non-response were lack of relevant experience or knowledge and lack of time. One participant who would not complete a questionnaire, for example, commented that he would only be guessing if he tried to complete the questionnaires since he had no experience of the risks in question. However, more probable explanations emerge from the analysis of the Pilot survey results. Although most of the respondents were very experienced in the industry and in risk management, the majority of the respondents normally limited their estimates of risk to, at best, a three-point estimating approach (minimum, maximum and most likely). There was thus a mental conditioning towards a triangular distribution and estimating other mid points of the distribution of the risk to reflect their full experience was not particularly comfortable for most of the respondents and initially time consuming. This offers helpful insights for risk management training for the industry. Similar reasons apply to the Ghana sample of experts.

Although all the experts from the financial class 1 contracting group and almost all of the consulting experts (excepting five foreign experts from the contracting organisation) expressed willingness to participate in the survey, most of the contracting experts from the financial Class 2 group did not provide any information of significance as they explained that they lacked adequate relevant experience. The main reason given by those consulting experts who declined to participate further was pressing commitments during the period of the survey that made the schedules for such "extra-curricula" engagements unreliable. The reasons given by the five foreign experts for their inability to be involved with the research included

(a) doubts about the true identity of the researcher. This was in spite of the use of the University of Edinburgh letterheads and the provision of the Researcher's Identity Card from the university which had the researcher's photograph,

(b) the fact they had not received any official notification about the research from the Ministry of Roads & Transport in Ghana from whom their details were obtained,

(c) the fact that they saw no relevance of the study to them since they simply sought remedies from within the terms of each contract whenever there was a default arising in, for example, delay in payment.

(d) the fact that they deal with risks on a project by project basis and therefore saw no merit in the statistical or probabilistic approach to risk management.

Despite these "official" reasons, it was the clear impression of the author during the interviews that these experts felt threatened by the potential outcomes of the research not only in raising awareness about contractual risks in Ghanaian Construction, but also in giving competitive insights to potential competitors both within Ghana and the UK about construction contract bidding in Ghana. Hence their unwillingness to divulge any information about their system for identifying and reducing risks (see section 5.1.7.(a)).

Table 5.3.1: Profiles of Main Survey samples

Country	*Category*	*Number Targeted*	*Number Selected*	*Number of Responses*	*Response Rate*
United Kingdom	Construction Experts	74	74	8	10.81%
	Consulting Quantity Surveyors	24	24	10	41.67%
	Total Respondents	98	98	18	18.37%
Ghana	Construction Experts	25	20	6	30.00%
	Consulting Quantity Surveyors	29	27	6	22.22%
	Total Respondents	54	47	12	25.53%

Figures 5.3.1 and 5.3.2 present the analysis of the respondents by number of years of industrial and professional experience, while Figure 5.3.3 summarises the extents of the risk management responsibilities of the UK respondents in the projects they have been involved with in the past 10 years.

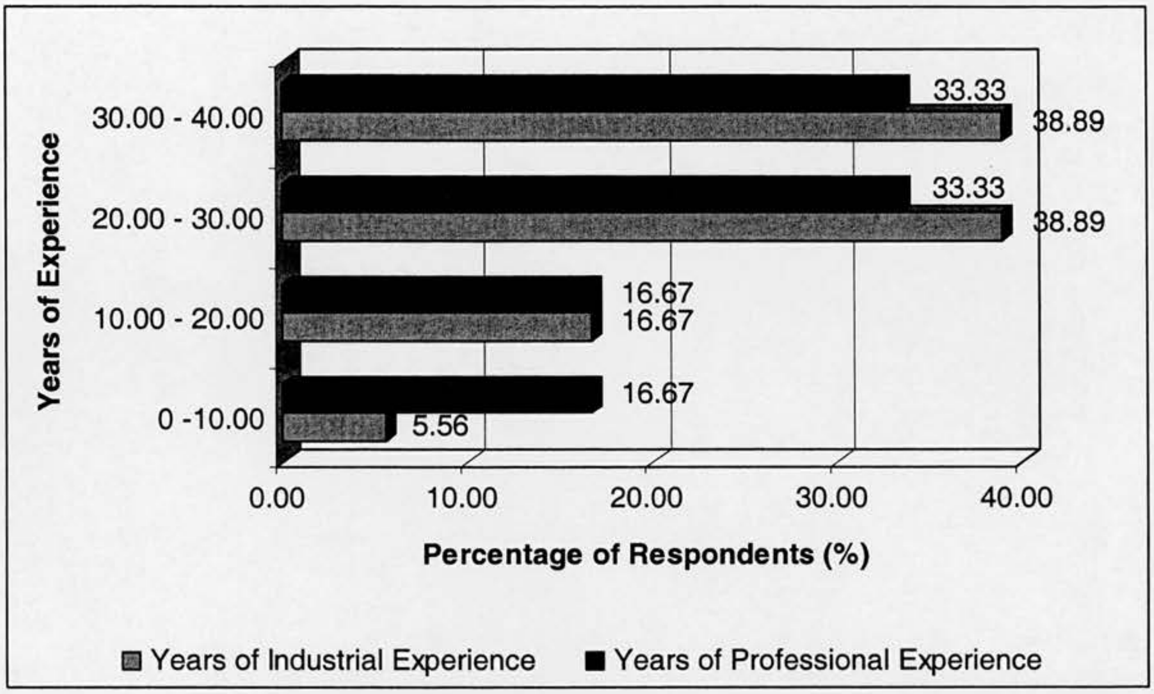

Figure 5.3.1: UK Respondents by years of Experience

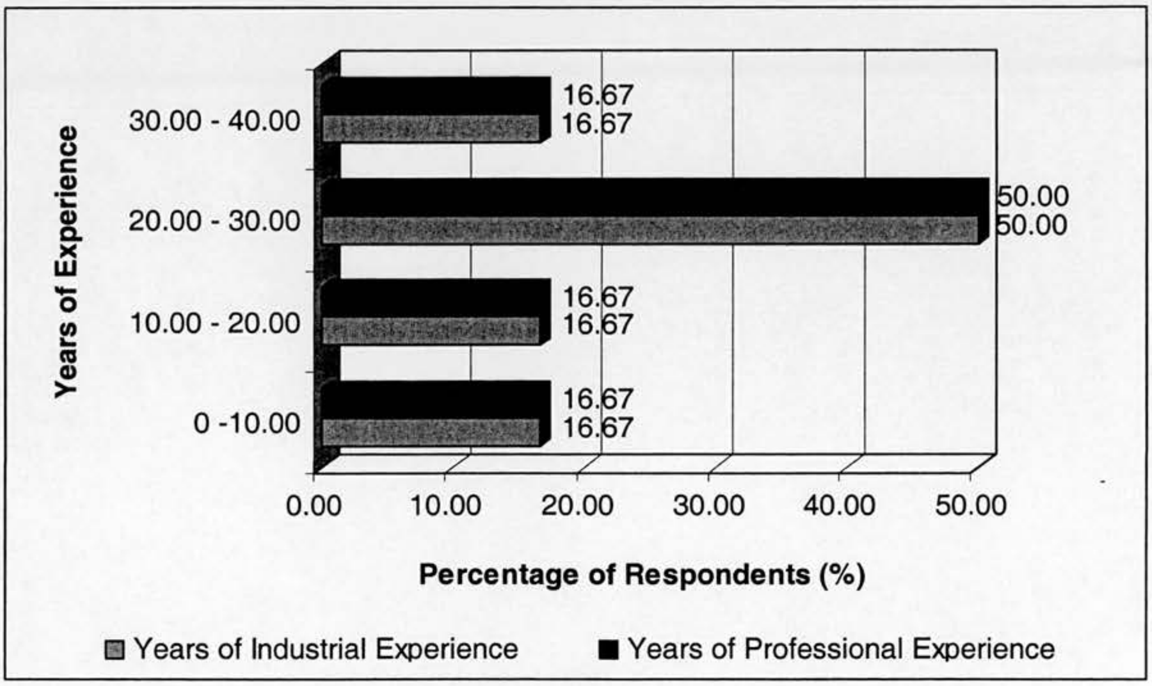

Figure 5.3.2: Ghana Respondents by years of Experience

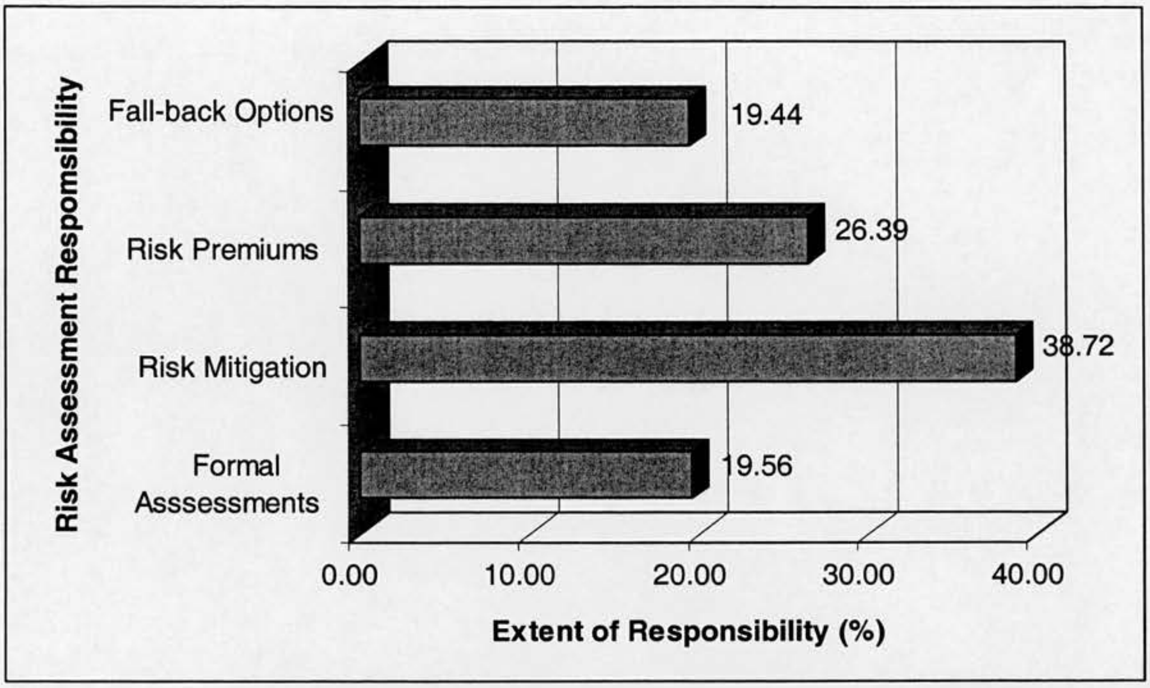

Figure 5.3.3: Extent of Risk Management Responsibilities of the UK Experts

As is evident through the Figures, over 80% of UK respondents had more that 10 years of professional experience, while the number with more than 10 years of industrial experience is almost 95%. For the Ghana survey, the number of respondents with more than 10 years of industrial or professional experience is over 80%. On average, UK respondents have each had a key risk management responsibility on about 20% of the projects with which they have been involved in the past 10 years.

The high percentages of experienced respondents and their levels of risk management responsibilities or involvement are important in that they highlight the significance of the estimates given, in the light of the works of Simonton (1996) and Vick (2002) discussed in section 4.4.2. If the expert estimates were based solely on their actual knowledge and experiences, the means of the estimates would equal or match very closely to the actual, (statistical) data obtained from the HSE, and all data points would fall on the 45° line in Figure 5.3.4. (Slovic *et al.*, 1980). Major variations of expert estimates from actual values would therefore signal the influence of individual perception rather than expertise. Furthermore, the use of unequal weighting in the aggregation of subjects' estimates (Winkler, 1967b; Hampton et al, 1973 and Ashton & Ashton, 1985) was disregarded for this study in view of the high values of the experts' years of experience.

5.3.2 Individual perceptions and Expert estimates about risks

Figures 5.3.4 to 5.3.6 are graphs of the mean values of the expert estimates about the occurrence and fatalities of the nine accidents/risks discussed above, plotted against the HSE values (actual recorded incidents) given by the 45° line which thus serves as the calibration graph for the expert estimates.

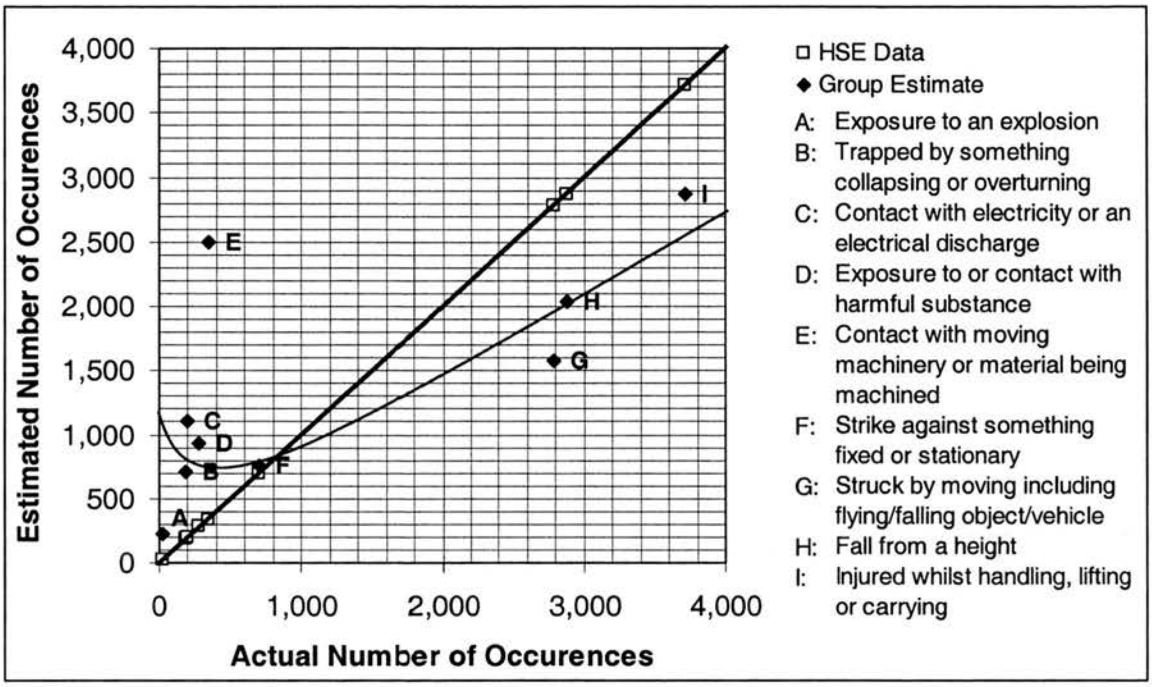

Figure 5.3.4: Relationship between Judged frequency and actual total number of accidents on a construction site in a normal year for 9 major site accidents

It is evident from the Figures that although, on average, the less occurring accidents were given lower estimates while the more frequent accidents evoked higher estimates for total numbers of accidents occurring in either a normal or a disastrous year, the less frequent accidents were consistently overestimated while the more frequent accidents were underestimated. In addition, the fatalities of less fatal accidents were overestimated while those of more fatal accidents were underestimated. In particular, "Contact with moving machinery or material being machined" was consistently very highly over-estimated as an accident, in terms of both the frequency in any year and the impact of its occurrence. The data points of the experts are therefore scattered around a best-fit curve that sometimes lies above and sometimes below the line of accurate judgement. These misjudgements are illustrative of the use by the experts of an availability heuristic (described in Section 3.3) in which events that are easier to imagine or recall are judged as relatively more frequent. However, the high overestimation of fatality of the risk of "Contact with moving machinery or material being machined" could be caused by the use of the representativeness heuristic.

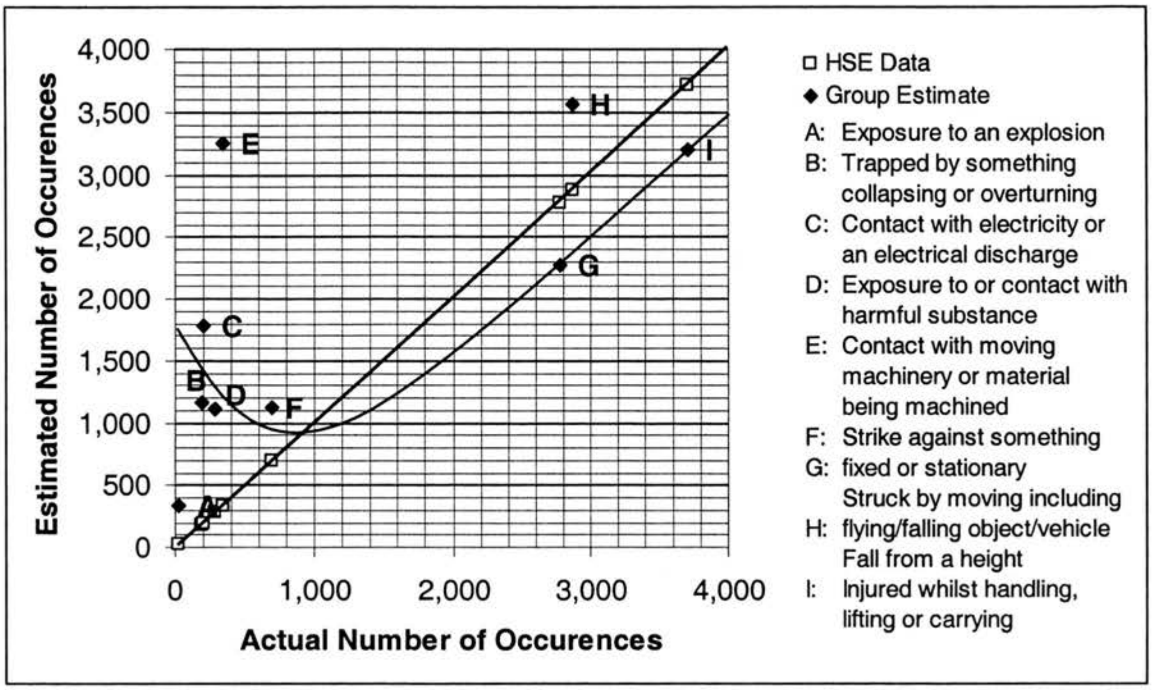

Figure 5.3.5: Relationship between Judged frequency and actual number of total accidents on a construction site in a disastrous year for 9 major site accidents

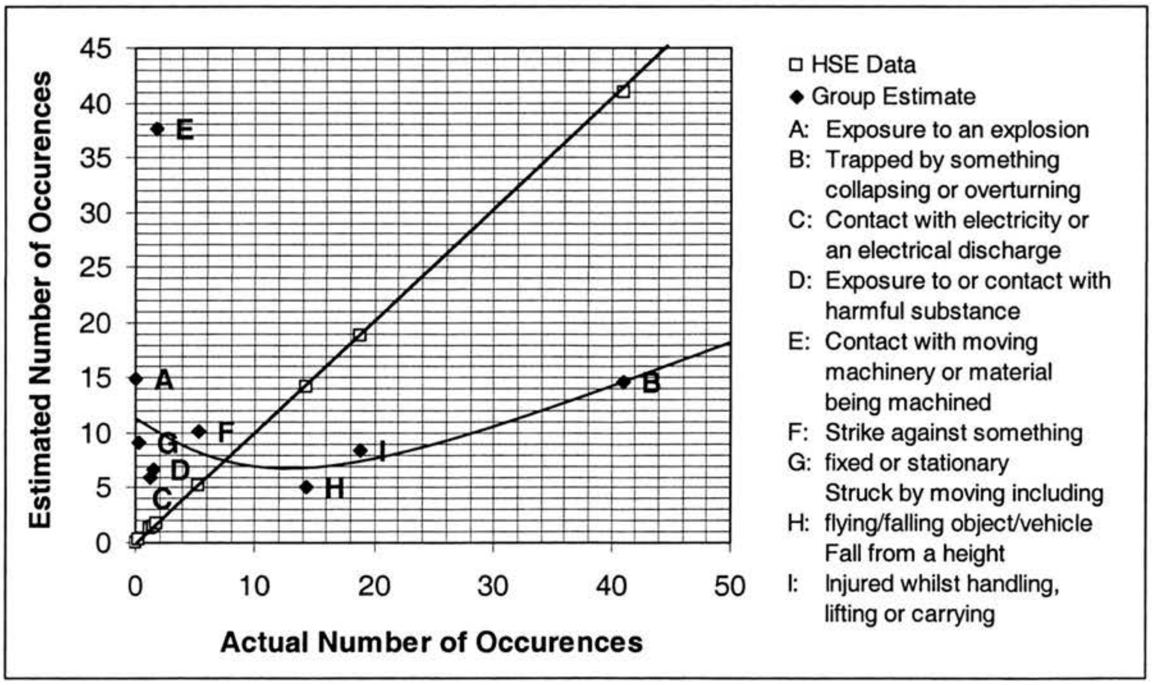

Figure 5.3.6: Relationship between Judged frequency and actual number of fatal accidents on a construction site in any year for 9 major site accidents

Construction sites often have heavy moving machinery and heavy and bulky materials that, although often have very low moving speeds, would cause one to think that inappropriate contact by a worker with any such machinery or material would result in fatality. Since moving machinery and materials are a constant feature of an active construction site (hence the high overestimation for the frequency of the risk of "Contact with moving machinery or material being machined"), one would also think that the risk has a high fatality rate.

The actual estimates of the individual experts are used for the graphs above are summarised in Tables 5.3.2 to 5.3.3 and Tables 5.3.4 to 5.3.5 which give estimates for a Normal year and a Disastrous year respectively. In the tables, a normal year for construction accidents purposes refer to any year in which the numbers of accidents are within what would be expected based on the annual average numbers of similar accidents in the few years preceding that year. A disastrous year refer to any year in which the numbers of accidents are either excessive or well outside the range of what could be expected based on the annual average numbers or range of similar accidents in the past few years preceding that year. Thus on average, The HSE averages per year are given in the second column of each table. An analysis of the individual expert estimates in Tables 5.3.2 to 5.3.5 also reveal two factors affecting the estimates. Experts with recent experiences of the risks (i.e. experienced the risk(s) within the preceding twelve months) generally gave higher than average estimates while experts no recent experience of the risk(s) (i.e. the most recent experience of the risk(s) was more than twelve months old) generally gave lower than average estimates. For example, Respondents 9 and 18 in the Tables have had no experience of any of the risks in the past twelve months. Their estimates for both occurrences and fatalities are consistently lower than the group average and in almost all instances also lower than the actual values. On the other hand, Respondent 13 has had three separate experiences of each of the risks of "Contact with electricity or an electrical discharge" and "Contact with moving machinery or material being machined" in the past one and 3 months respectively. This expert's estimates of these risks are exceptionally much higher than both the HSE and group averages. In fact, his estimates of the occurrences of these two risks are the main contributing factors to the exceptionally high group averages for the two risks!

However, there are some exceptions to these general patterns. For example although respondent 14 has had frequent (ranging from three to eight separate) experiences of almost all the risks in the last one to twelve months, Respondent 14's estimates are consistently lower than the HSE and group averages (with the exception of the estimate for the risk of "Injured whilst handling, lifting or carrying"). It is fair to conclude that Respondent 14 is generally an optimist. This respondent's estimating behaviour can be contrasted with that of Respondent 19 who may be described as a pessimist. Although almost all of the respondent's experiences of the risks are over a year old and only the risk of "Struck by moving including flying/falling object/vehicle" was fatal, the respondent's estimates are generally higher the HSE and group averages. Surprisingly (or perhaps not so surprisingly), although his estimates for the fatalities of the risk of "Struck by moving including flying/falling object/vehicle" were expectedly high, his estimates for the frequencies of the risk are lower than both the HSE and group averages. One possible explanation is that although he did not consider the risk to have a high likelihood of occurrence based on his general experience (his most recent experience of the risk was over a twelve months old), his recollection of the fatality of the last experience of the risks makes him believe that that the accidents would be fatal if they occur. This estimating behaviour is again an illustration of the use of the availability heuristic. It perhaps also gives further evidence to the heuristic of judgement by catastrophic/disaster potential discussed by Slovic *et al.* (1980).

These observations about the estimating behaviours of the experts only go to confirm the assertion that differences in individual perceptions about risks will result in differences in their estimates about the same risks.

Tables 5.3.2: Respondent's Estimate of the total number of accidents in a Normal Year

Accident	HSE	Respondent's Estimates																	
Or Risk	Average	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	23	10	200	20	50	50	500	10	30	0	2,500	10	200	25	30	10	400	2	20
B	184	50	100	50	300	500	5,000	100	300	2	5,000	50	150	100	600	100	200	10	50
C	194	20	400	20	20	3,000	5,000	10	140	2	10,000	50	500	100	150	100	300	5	35
D	280	50	350	100	100	5,000	3,000	100	135	10	5,000	20	500	175	30	100	2,000	15	20
E	339	20	100	50	500	200	500	100	250	10	40,000	1,000	200	250	100	200	1,500	15	30
F	694	100	50	100	100	1,000	1,000	50	240	5	10,000	200	20	200	100	100	400	20	40
G	2,780	100	200	100	200	300	5,000	50	220	2	20,000	500	300	150	150	100	1,000	20	40
H	2,873	500	100	50	500	1,200	10,000	500	1,450	2	10,000	100	1,000	200	1,500	400	9,000	10	100
I	3,711	1,000	500	100	500	5,000	10,000	1,000	160	20	10,000	20,000	700	200	150	300	2,000	30	100

A: Exposure to an explosion; **B**: Trapped by something collapsing or overturning; **C**: Contact with electricity or an electrical discharge
D: Exposure to or contact with harmful substance; **E**: Contact with moving machinery or material being machined; **F**: Strike against something fixed or stationary, **G**: Struck by moving including flying/falling object/vehicle; **H**: Fall from a height; **I**: Injured whilst handling, lifting or carrying

Tables 5.3.3: Respondent's Estimate of the number of fatal accidents in a Normal Year

Accident	HSE	Respondent's Estimate																	
Or Risk	Average	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	0	2	25	5	10	5	5	5	8	2	100	5	2	6	3	2	75	5	3
B	0	10	30	30	10	10	20	5	8	1	50	2	5	7	15	2	50	5	4
C	1	2	5	0	10	5	5	0	8	1	50	0	1	4	0	0	10	3	4
D	2	2	10	0	50	0	10	0	5	1	10	1	10	0	2	1	10	0	8
E	2	10	3	20	100	20	100	20	50	1	50	3	15	8	150	10	100	8	10
F	5	2	10	10	10	15	20	2	10	1	25	2	1	4	30	5	20	7	8
G	0	2	5	0	5	5	5	0	5	1	25	0	3	3	1	1	100	0	2
H	14	2	5	5	20	5	10	1	1	0	10	0	1	3	1	1	25	1	1
I	19	2	5	10	20	10	5	1	5	1	50	2	2	5	5	2	20	2	3

A: Exposure to an explosion; **B**: Trapped by something collapsing or overturning; **C**: Contact with electricity or an electrical discharge
D: Exposure to or contact with harmful substance; **E**: Contact with moving machinery or material being machined; **F**: Strike against something fixed or stationary, **G**: Struck by moving including flying/falling object/vehicle; **H**: Fall from a height; **I**: Injured whilst handling, lifting or carrying

Tables 5.3.4: Respondent's Estimate of the total number of accidents in a Disastrous Year

Accident Or Risk	HSE Average	Respondent's Estimates																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	23	20	400	40	55	200	1,000	20	60	2	3,125	20	230	25	33	50	800	10	25
B	184	100	200	100	330	1,500	10,000	200	350	3	6,250	70	173	100	660	300	400	15	100
C	194	40	500	40	22	7,000	10,000	20	140	3	12,500	80	575	125	165	200	600	10	50
D	280	100	450	200	110	1,500	6,000	200	180	20	6,250	30	575	175	33	200	4,000	25	30
E	339	100	200	100	550	500	1,000	200	300	20	50,000	1,500	230	300	110	400	3,000	25	50
F	694	200	150	200	110	3,000	2,000	100	300	7	12,500	200	23	275	110	200	800	40	40
G	2,780	200	300	200	220	700	10,000	100	350	5	25,000	750	345	200	165	300	2,000	30	60
H	2,873	1,000	200	100	550	3,000	20,000	1,000	1,700	3	12,500	150	1,150	290	1,650	600	20,000	20	250
I	3,711	2,000	750	200	550	10,000	20,000	2,000	170	25	12,500	3,000	805	275	165	1,000	4,000	50	150

A: Exposure to an explosion; **B**: Trapped by something collapsing or overturning; **C**: Contact with electricity or an electrical discharge
D: Exposure to or contact with harmful substance; **E**: Contact with moving machinery or material being machined; **F**: Strike against something fixed or stationary, **G**: Struck by moving including flying/falling object/vehicle; **H**: Fall from a height; **I**: Injured whilst handling, lifting or carrying

Tables 5.3.5: Respondent's Estimate of the number of fatal accidents in a Disastrous Year

Accident Or Risk	HSE Average	Respondent's Estimate																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	0	4	20	20	17	40	40	4	12	1	31	3	2	6	33	10	40	10	8
B	0	4	15	20	22	30	10	2	7	1	63	4	3	10	6	5	40	4	6
C	1	4	40	10	11	18	10	10	10	2	125	10	3	8	4	10	150	10	5
D	2	4	20	0	55	3	20	0	6	1	13	3	13	2	3	5	20	5	5
E	2	20	10	40	110	50	200	40	60	1	63	5	20	14	165	30	200	15	20
F	5	4	20	0	11	10	10	0	10	2	63	1	2	6	0	5	20	10	4
G	14	20	40	60	11	20	40	10	12	2	63	3	7	10	17	5	100	12	6
H	19	4	15	0	7	20	10	0	6	2	31	1	4	5	2	5	200	5	3
I	41	4	15	10	22	10	20	2	2	1	13	2	2	5	2	3	50	5	2

A: Exposure to an explosion; **B**: Trapped by something collapsing or overturning; **C**: Contact with electricity or an electrical discharge
D: Exposure to or contact with harmful substance; **E**: Contact with moving machinery or material being machined; **F**: Strike against something fixed or stationary, **G**: Struck by moving including flying/falling object/vehicle; **H**: Fall from a height; **I**: Injured whilst handling, lifting or carrying

5.3.3 The impact of socio-culture on the perception and estimates of risks

Figures 5.3.7 and 5.3.8 below represent the PDFs and hence the belief functions of experts from the UK and Ghana regarding the occurrence and the impact of the risk of payments delays in an international construction project in Ghana. Table 5.3.6 summarises the comparisons of the statistical descriptors and measures of the PDFs derived from the estimates Ghana and UK experts (Figures and 5.3.7 and 5.3.8). As the Figures and Table demonstrate, the probability distributions or "belief functions" of the two groups of experts are clearly different.

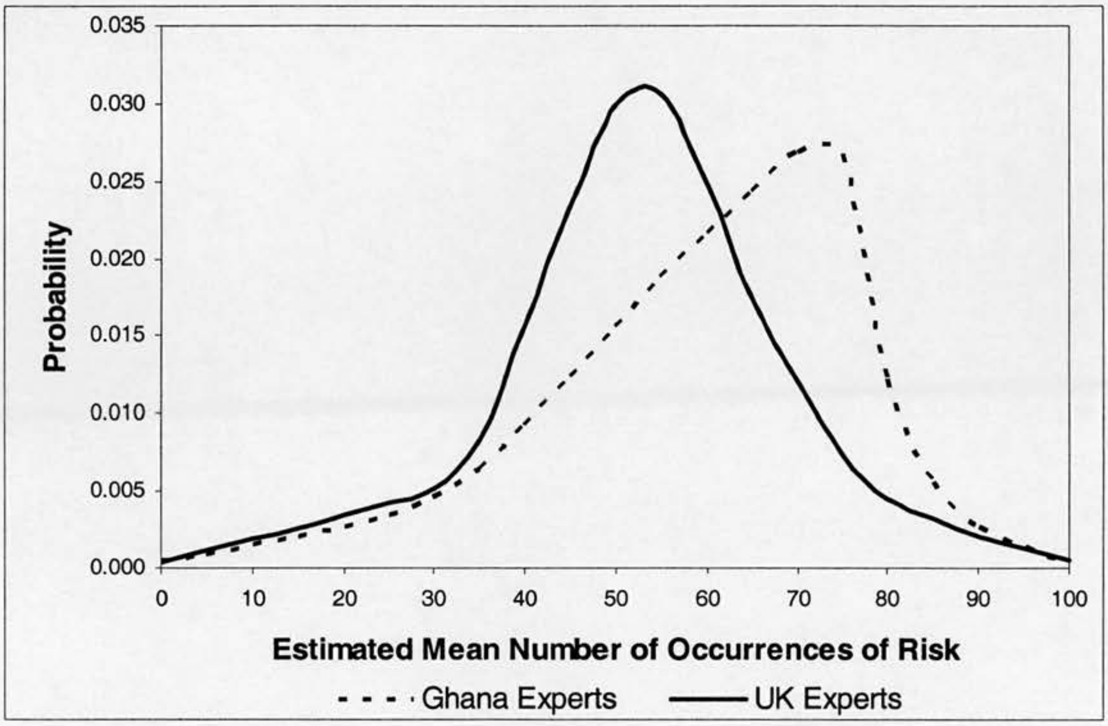

Figure 5.3.7: PDF for Occurrences of the Risk of Payment Delays

The results of this part of the survey are rather interesting. Although it was generally expected based on the findings of (Cullivan, 1981) and the experience of the author about how the tender prices of foreign contractors working in Ghana are almost always higher than those of the local contractors, that mean estimates from UK experts about risks in Ghana would be consistently higher than their Ghanaian counterparts, the survey results do not necessarily confirm this expectation. Table 5.2.2 revealed that on average, the mean estimates of the risk attributes by the Ghanaian experts are almost consistently higher than mean estimates from the UK experts.

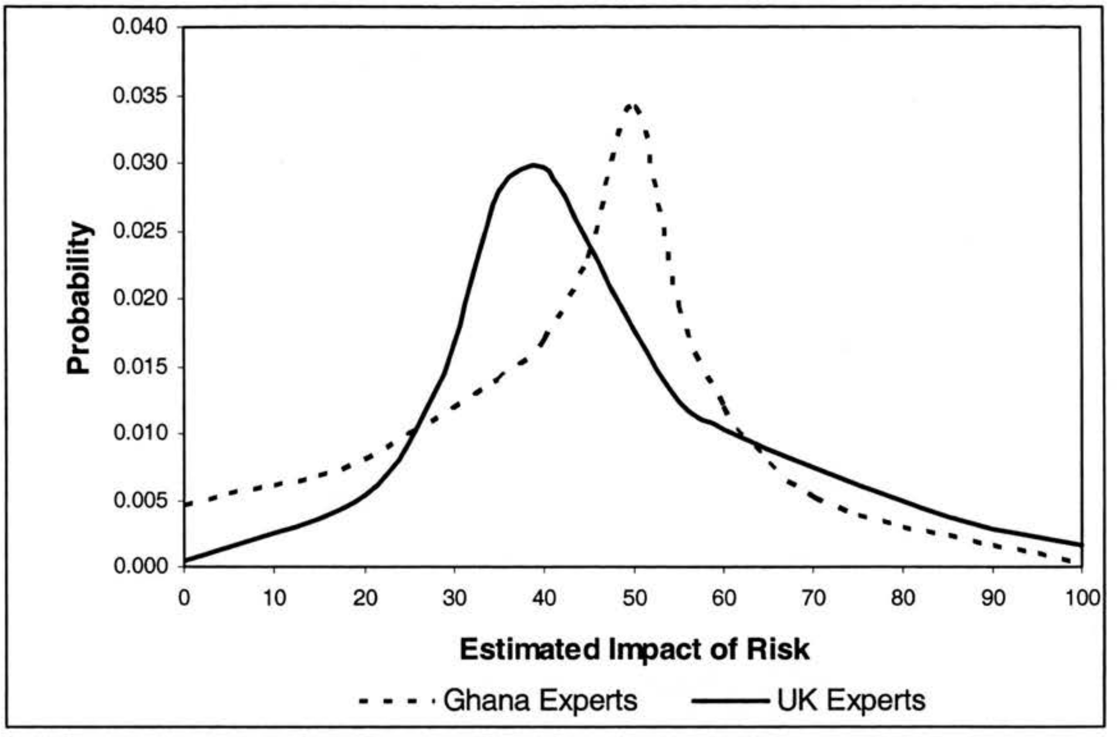

Figure 5.3.8: PDF for the Severity of Impact of the Risk of Payment Delays

Tables 5.3.6: Comparison of Statistical Descriptions of Smoothed Rating Values

Statistical Measure	Risk Likelihood		Risk Impact	
	Ghana	UK	Ghana	UK
Minimum	0	0	0	0
Maximum	100	100	100	100
Mean	59.63	52.73	43.85	46.24
Mode	73.00	53.00	52.00	38.00
Median	62.54	53.04	46.47	42.94
Standard Deviation	17.25	15.94	18.80	18.37
Sample Variance	297.48	254.04	353.27	337.42
Skewness	-0.75	-0.22	-0.08	0.57
Kurtosis	3.43	3.70	3.06	3.21

However, the estimates of the UK experts for the minimum and maximum impact of the occurrence of the risk are higher than similar estimates from the Ghana experts. The same is true of the minimum number of occurrence of the risks. It appears as though in pricing risks in overseas projects, the UK contractors either is mainly concerned with their perception of the minimum and maximum values of the occurrence of risks and the impact of the risks should they occur, or assigns financial premiums to the impact of the risks that are much higher than what the actual financial impact would be. On the other hand, the Ghanaian contractors demonstrate over-confidence towards mitigating the risks should they occur (see section 5.1.7.(b)), and therefore do not price the risk in accordance with their perception of the likelihood and impact of the risk. As discussed in section 5.2.7.(b), this attitude is widespread among Ghanaian contractors.

It is evident from these results that perceptions and attitudes of the two groups of experts are significantly different, although the dispersions of estimates within the groups are very similar within each group. These findings seem to support the assertion that differing socio-cultural backgrounds of risk experts will lead to significant differences in their estimates the same risks.

5.4 A Model for eliciting subjective expert estimates: An application

Data for this part of the study came from the main studies conducted in both the UK and Ghana and Section 5.3.1 presented the survey sample and respondent characteristics of the two sets of surveys involving the four survey instruments in Appendices 4 and 6, which were designed to test the effectiveness of the elicitation model in eliciting subjective estimates of attributes of the same risks from expert of different cultures/countries. The estimates sought were to be developed into subjective priors to help answer the questions:

> "*What is the probability that there will be a delay in project completion in an international construction project set in Ghana and for which the Client is the Government of Ghana, if there is a payment delay by the Ghana government?*",

and

> "*What will be the nature of the impact of the risk of payment delay on such a project should the risk occur on the project?*"

To answer the first question the schedule sought to elicit expert estimates that could be developed into subjective prior probability distribution for the risk of payment delay on such a project. Coupled with the sample information that was also obtained using the same schedule (due to the resource constraints on the research), Bayesian analysis could then be applied to arrive at an answer to the first question as:

$$P(x|\theta_1) = \frac{P(\theta_1|x)\sum P(\theta_i)P(x|\theta_i)}{P(\theta_1)} \qquad \text{(Equation 3.2.5)}$$

where in this instance,

$P(x\|\theta_1)$	is the probability of project delay if/given that there is a payment delay
$P(\theta_1\|x)$	is the probability of payment delay given that there is a project delay.
$\sum P(\theta_i)P(x\|\theta_i)$	is the probability of project delay (arising from all risk sources)
$P(\theta_1)$	is the probability of payment delay

Expert estimates for the second question would also be developed into subjective prior probability distribution for the scale of impact of risk of payment delay on such a project. Since a scale of 1-100 was used to define the range of the impact scale for the risk, actual monetary or other resource values can be assigned to distribution of the impact scale. If the probability distribution of the risk impact scale is represented by $P(\beta)$ and then

P[*Risk*] = P[*Risk Likelihood*] *X* P[*Risk Impact*]

$= P(x|\theta_1) \times P(\beta)$

The results and the analysis of the elicited estimates of expert judgements for the likelihood and impact of the risk of payment delay were presented in section 5.3. As explained in the preceding section, the use of the Scaling technique for eliciting subjective estimates was discarded in the main study. The initial analysis of the survey data revealed some initial in coherencies among the estimates of the experts from Ghana similar to the type discussed in the preceding section. These were discussed with the experts in telephone feedback during which adjusted estimates were given by the experts. The effective capturing of the problem representations of the two groups of experts by the elicitation model and the ability of the questioning and response methods to enable most of the experts to self-elicit their own beliefs and transform them into probability representations are very powerful confirmations of the effectiveness of the elicitation model presented in section 5.2.1.

Based on the responses from the experts, we are able to determine $\sum P(\theta_i)P(x|\theta_i)$ from the sample information by the ratio of how many projects had completion delays over the past ten years (Section 2, question 8 of Appendix 4) to the total number of projects executed over the same period (Section 3, question 1 of Appendix 4). The sample evidence from the Ghana survey is summarised in Table 5.3.7. Similarly, we are able to determine $P(\theta_1|x)$ by the ratio of how often we find that there was a payment delay in projects that had delayed completion over the same period (Section 2, question 8(i) and 8(ii) of Appendix 4).

Table 5.3.7: Sample Evidence from the Ghana Survey

Sample Information	Value
Total Number of International Projects	31
Total Number of Projects with completion delays	17
Total Number of Projects with completion delays that had payment delays	12

From Table 5.3.4 we have

$$\sum P(\theta_i)P(x|\theta_i) = \frac{17}{31} = 0.55$$

$$P(\theta_1|x) = \frac{12}{17} = 0.71$$

The elicitation model enabled us to derive $P(\theta_1)$ which can be mapped to an appropriate distribution, thus enabling us to have all components necessary to determine $P(x|\theta_1)$, the probability of project delay if/given that there is a payment delay using Equation 3.2.5

5.5 Specific limitations on the analysis by the Survey Data

While the data generated was sufficient to demonstrate the achievement of the objectives of the research, it does not allow the author to conduct other types of statistical and probabilistic analyses that would be of further academic interest. For example, given a larger set of responses, it is possible to obtain continuous probability distributions of all the components of the Bayesian solution for $P(x|\theta_1)$ and thereby be able to apply a simulation approach such as Monte Carlo simulation to derive a distribution for $P(x|\theta_1)$ upon which decisions can be made. The current data can only allow the use of point estimates from the sample information for deriving a Bayesian solution for $P(x|\theta_1)$. However, the lack of large and useable sets of data is not the result of the nature of the survey instruments or approaches used, as the efficacy of the survey instruments and approaches had verified through a number of scholarly and expert reviews and pre-tests (see sections 4.2 and 4.7). For example, during the Ghana survey, it became apparent that although almost all the respondents found the study interesting, they often found the questionnaire difficult to deal with. The cause of the confusion was identified to be the fact that they had to deal with a number of risk issues on the same questionnaire. Apart from the fact that this gave an immediate impression that a lot of work was required by the questionnaire, it also did not help to focus their minds on a particular risk at a time. This problem was not faced during the pilot survey in which respondents had to deal with just one risk. Most of the respondents exhibiting the difficulty of dealing with more than one risk at a time appeared to easily regress into thinking about responses to different risk and providing estimates for a number of risks at the same time. This often created a situation where a "correct estimate" was assigned to a risk to which the estimate does not apply. Changes were immediately made in the questionnaire in Ghana to correct this, and the questionnaire for the main UK survey was subsequently also revised to elicit estimates about only one risk.

In addition, the data that the survey was able to generate is the result of considerable effort in both the UK and Ghana over an extended period of time. For example, the research data from the UK surveys were arrived at after a number of reminders to the pre-qualified experts, including two sets of mail/fax reminders and countless phone reminders. One of the main reasons for the difficulties in obtaining that data from the experts appear to be the difficulty currently encountered by construction professionals in estimating intermediate and tail values of a probability distribution and the possible further mental conditioning caused by the frequent use of the triangular distribution for most analytical work in construction estimating (Chapman & Ward, 1997). The present research being the first of its kind in the industry certainly posed a significant challenge to the majority of the experts. It is the belief of the author that the common reasons of lack of relevant experience and lack of time given by the respondents was really the result of the difficult they faced in accurately expressing their beliefs regarding the intermediate and tail values, and the concomitant length of time it would therefore take to complete the questionnaires.

Three visits were made to Ghana for research data collection. The initial visit which lasted two weeks was helpful in obtaining general but up-to-date country-specific information that would inform the development of the survey instruments for the main survey. The visit also helped the author to re-establish both industrial and political contacts that would be helpful later on in obtaining the research data. The visit for the main survey lasted three months and involved travelling across the country to Accra and surrounding areas, Kumasi and Tema, three of the major cities in the country which together has over 70% of the total population of construction experts in the country (based on the lists obtained from the Ministry of Road & Transport, the Ghana Highway Authority and the Architectural and Engineering Services Corporation). The third visit which also lasted two weeks was a follow-up visit mainly aimed at obtaining data from experts who had agreed to participate but who could not complete their questionnaires before the end of the second field visit to Ghana.

The poor response rate from the Ghana survey was due to other factors that were additional to the ones explained above. Because the government is the key client for the majority of the contracting companies in the country, local contractors tended to do whatever they needed to do not only to win contracts, but to also keep within the "good books" of the government by working with the government to ensure successful projects in spite of defaults by the government and other risks. It is the belief of the author that this prevailing attitude conditions their response to risk and therefore limits risk problem representations among the Ghana experts, as risks are generally not dealt with in any systematic manner. The phrase "*we don't normally do things this way*" was very commonly heard from the targeted participants who did not complete the questionnaires. The questionnaires therefore required more time to complete among the Ghana experts. For example, two of the Ghana respondents each needed over two hours of interviewing time to complete the Risk Impact questionnaire (appendix 4). Six of the respondents required two meetings lasting over 90 minutes each to compete the questionnaire. All attempts to have the questionnaires completed by the non-responding experts failed. The perception among some of the experts of the study posing a "threat" was another unhelpful factoring the Ghana survey.

While these difficulties pose a limitation on the extended analysis that the author had intended to do with the research data, they provide very helpful insights that support the aims of the research. For example, the reasons for non-response encountered by the research would be a non-issue if the elicitation were being conducted by a company for its' own benefit. Information would be more forthcoming from among the company's experts. The data obtained also demonstrate the error involved in the popular use o the triangular distribution for contractual risk analysis. This calls not only for a new approach to risk management training in construction, but also for a re-thinking of the distribution forms used in construction risk analysis.

5.6 Summary

This chapter set out to present the results and analyses of the research survey conducted among construction experts in the United Kingdom and Ghana, in line with the objectives of the research. The results were presented along the three-fold objectives of the research outlined in Chapter 1 and the order in which the research was carried out. Section 5.1 presented evidence and analyses that validated the assertions that although applications and use of systematic and rigorous probabilistic methods to risks in other industries can only point to the enormous potential that such methods present to the construction industry, there is very little application, if any, of systematic and rigorous probabilistic methods to contractual risk in construction, and that analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques. This section also presented an analytical overview of risk management practices in Ghana which confirmed that the situations in the two countries are very similar. Section 5.2 presented the development and testing of the model for eliciting subjective expert opinions as input variables to probabilistic risk analysis. In Section 5.3, evidence and analyses that validated the assertions that differences in individual perceptions about risks will result in differences in their estimates about the same risks, and that differing socio-cultural backgrounds of risk experts will lead to significant differences in their estimates the same risks. In section 5.4, analysis of the data confirming the effectiveness and efficacy of the elicitation model and hence the applicability of expert elicitation, subjective probability and Bayesian analysis techniques to contractual risks was presented. These three sections effectively provided confirmations for the research assertions, and the achievement of the research objectives.

The next Chapter concludes this report with the major insights and research findings, research generalisations and the main conclusions of the research. The Chapter also presents the limitations of the study and the key recommendations for further research and contractual risk analysis in the construction industry.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

In a lecture delivered at the Massachusetts Institute of Technology on November 10, 1993, John A. Armstrong former IBM Vice-President of Science and Technology described the tasks involved in doctoral research:

> *"To earn a Ph.D. in science or in engineering research, a young person is expected to make an original contribution to science or engineering science. It is expected that the graduate student will ask a narrowly defined set of questions and, within that narrow region, think and/or experiment deeply. He or she must learn how to pose a problem, decide what data or experiments are required to solve it, obtain that data, analyse it critically, draw conclusions, and then defend those conclusions vigorously. In the process, the student has discovered how to acquire new skills, including the ability to understand and use just about any form of applied mathematics. The student has, in a word, learned how to learn at a very sophisticated level"* (Armstrong, 1994).

Phillips & Pugh (1994) agree with these essential requirements for such high-level investigation in their definition of the criteria for doctoral level research and of originality of work in the context of a PhD research. This Chapter thus closes the curtain on this report by drawing together the essential insights from the body of knowledge that existed prior to the current research and the main findings of the research, and thereby answer, in concise forms, some of the key questions involved in high-level scholarly research:

(a) What gaps in the existing body of knowledge or practice prompted the current research and how did the current research seek to close these gaps?

(b) What useful and novel findings did the current research make and what are the implications of these findings on the research objectives?

(c) To what extent does the current research reflects or impacts on the international context of the subject matter of the research and how does the research findings add to the existing body of knowledge on the subject matter of the research?

(d) What limitations are imposed on the research findings by the techniques and processes applied in the investigation, and hence to what extent can the findings of the research be interpreted and applied?

(e) What are the implications of the research findings and limitations on future research and professional practice in the subject matter of the research?

Key insights that emerge from the literature regarding the objectives of the study are summarised in Section 6.1. The specific findings of the empirical survey are discussed in Section 6.2 which is presented under the three key objectives of the research. Section 6.3 summarises the main conclusions of the study and the statistical, analytical, cross-cultural and economic/market implications of the findings. Section 6.4 highlights the limitations of the research which, coupled with the findings of the research, provide the basis for recommendations for future professional practice and research discussed in Section 6.5.

6.1 Key insights from existing works

Like all investment projects, construction projects involve significant financial/economic risks and formal, systematic and rigorous processes have been applied to the analysis of financial risks in construction with significant success (Pouliquen, 1970; Chapman, 1979; Perry & Hayes, 1986; Cooper & Chapman, 1987; Russell & Ranasinghe, 1992; Flanagan & Norman, 1993). One of the key factors underlying such systematic and rigorous analyses is the recognition that the very nature of risks and uncertainties presents variability in project outcomes the full range of which needs to evaluated in order to make sound investment decisions. However, financial risks are not the only risks encountered in construction. Construction projects involve numerous contractual relationships through which the possible but unexpected, undesirable and often rare outcomes of the project elements are distributed. These undesirable outcomes that are distributed through the contractual relationships are "contractual" risks which, like financial risks, also have a range of variability in their occurrences (Murdoch & Hughes, 1992). This begs the question: why are such risks not subjected to similar formal, systematic and rigorous analysis as financial risks, even though the existing approaches to their analysis are perceived (and rightly so) as being arbitrary, illogical, inadequate and misleading (Chapman, 1991; Hayes *et. al.*, 1986; Mok *et. al.*, 1997)? The need for an answer gets even more pressing when one considers the impact of perception and culture on personal estimates and interpretations of such risks (Slovic *et al.*, 1970; Li & Karakowsky, 2001), the current trends in procurement systems towards mixed packaging and transfer/sharing of risks, the implications of the current contractual risk analysis approaches on the competitiveness of British and other Western contractors in international construction especially within the emerging economies, and evidence from other industries with similar risks as construction contractual risks that have successfully been using elicitation techniques to encode subjective expert estimates of risks as input variables for the systematic and rigorous analysis of the risks (Cullivan, 1981; Murphy & Winkler, 1984; Spiegelhalter *et. al.*, 1994; Daponte *et. al.*, 1995; Kadane & Wolfson, 1997; O'Hagan, 1997; O'Hagan and Haylock, 1996)

The traditional approach in answering the question raised above has often been to blame the lack of rigour not only on the extra cost of pursuing a rigorous and systematic process (Simister, 1994), but also on the unavailability of relative frequency data on the separate risks, particularly to individual companies (Wright & Ayton, 1987). The second answer reveals the fundamental "frequentist" flaw that asserts that the only acceptable form of rigorous analysis is the "frequentist" approach. Furthermore, the evidence exhibited by the literature reveals that in the process of acquiring expertise, experts in any field develop such rich graphical imagery of patterns and well-developed problem representation in their minds, that enables them to sort, characterise and recognise the patterns in problems not only by their outward features but also by their underlying nature and thereby enable them to analyse problems and reach decisions in an expert-like manner (Vick, 2002; Simonton, 1991 and 1996; Patel & Groen, 1991; Patel, *et al.*, 1996; Glaser & Chi, 1988). Thus, in the absence of relative frequency data, expert judgements can be encoded and aggregated to provide useful data for analysis in a similar (and yet more formal, systematic, rigorous and accurate) manner as the experts do in arriving at decisions given uncertain data. This approach also minimises the impact of personal perception on individual expert estimates (Ashton & Ashton, 1985; Hubbard & Ashton, 1985; David *et. al.*, 1998; Grayson, 1998; Kendrick, 2003). The literature reveals that Bayesian analysis also provides further opportunities for contractual risks analysis that had not yet been fully explored (Tversky & Kahneman, 1971, Phillips, 1973; Ravinder *et. al.* 1988; Chau, 1995; Dunson, 2001; Vick, 2002; Rabin, 2002). These and other published works only give further credence to how other industries have been able to use elicitation techniques to encode subjective expert estimates of risks as input variables for the systematic and rigorous analysis of risks that otherwise do not have sufficient relative frequency data to allow a frequentist analysis. The work of Batty (1996) and the findings of the current research find the first answer to be also flawed and misconceived, and unsupported by the existing work on risk analysis.

These insights lead to the contentions, from the outset the study, that

(a) there is very little application, if any, of systematic and rigorous probabilistic methods to contractual risk in construction;
(b) analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques;
(c) differences in individual perceptions about risks will result in differences in their estimates about the same risks;
(d) differing socio-cultural backgrounds of risk experts will lead to significant differences in their estimates the same risks;
(e) similar techniques and processes used for eliciting quantified expert opinions for economic risks analysis, are suitable for generating similar estimates about comparable contractual risk from construction experts;
(f) the quantified opinions obtained from construction experts can be developed into probability estimates that can be used as input variables for the subjective probability analysis of contractual risks.

The central aims of this study have therefore been to conduct a review and survey to establish the types of risk management techniques currently used in the construction industry and the extent of their use, to investigate risk perception in the construction industry and its impact on project performance, and to develop a procedural model for the elicitation of expert opinions about risks that minimises the adverse effects of risk perception on individual estimates of risk, and provides these opinions as an input variable to the systematic and effective analysis of contractual risks. Extensive reviews of the literature spanning various fields, including engineering and construction, project risk management, research theory, cognitive psychology and probability and elicitation theories, were conducted not only to inform the discussion, but to also shape the investigation aimed at testing and validating these research assertions. The method for the investigation involved a hybrid of positivist and interpretative approaches to research in order to capture the totality of the evidence available (Onwuegbuzie, 2002). Some helpful findings emerge from the investigation that confirms the assertions of the research.

6.2 The specific findings of the Research

The research investigation has been pursued around the six related assertions described above which together sought to test the three key aspects about contractual risks in construction (the research objectives) relating to

(a) types and extent of use of risk management techniques in the construction
(b) risk perception in construction and its impact on project performance
(c) developing a model for eliciting quantified opinions about contractual risks

Findings regarding these objectives are discussed in turn below.

6.2.1 Types and extent of use of risk management techniques in construction

The study found that the extent of application of systematic and rigorous probabilistic methods to contractual risk in construction is very scant and that the analytical methods currently used to manage contractual risks in construction do not adequately deal with the effect of perception on the subjective estimates used in these analytical techniques. On the types of risk assessment used for example, the study found among UK construction experts that the tasks of risk assessment are undertaken predominantly (about 76%) by one individual within the organisation. This is particularly so among Quantity Surveyors (within both contracting and consulting companies) about 83% of whom use this approach. This usage is consistent with levels of usage within the Among Quantity Surveying firms, the usage level is over 93% compared to the 13% who use the In-house Multidisciplinary Group approach. On risk identification, the study found that "pondering" and "checklists" are the key risk identification techniques employed in the construction industry in the UK. All the survey respondents use "pondering" to varying degrees and about 85% of respondents use it at least 'frequently'. All (except one) of the respondents also use "checklists", about 72% of respondents using them at least "frequently". "Synectics" and Expert Interviews are the least used among almost all the construction professions in the UK. On risk likelihood assessment techniques, the study found that the predominant practices in the UK involve the use of scaling methods and subjective probability assessments. This is not surprising, as contractual risks by their nature do not lend themselves easily to the use of quantitative probability assessments. It is interesting to note however, that although scaling methods and subjective probability assessments are used in risk likelihood and impact assessments, they are on average not used "frequently' and the assessments are generally conducted using the In-house Individual approach. On risk impact analysis, the study found that the forms of analyses that are applied in economic risk analysis are very much an unexplored area when it comes to contractual risk analysis in construction. Generally, none of the techniques surveyed by the study is used to any significant degree. On average, probability analysis, sensitivity analysis, scenario analysis and ranking options are generally either never used or used only occasionally. It is also significant that no other methods of risk analysis are used by any of the respondents.

The reliability of these findings is reinforced by the results obtained through the analysis of the Mean Rating Values (MRV) of the various techniques. The only risk management techniques used that had a MRV of more than "2" ("2" signifying that the technique is used frequently) are "pondering" and "checklists". The case among Ghana experts is no different from the findings of the UK study. The predominant type of risk assessment used is the Individual Expert Assessment approach. This was done by either an in-house or an external expert. Although it was not normal practice to conduct risk identification on a project-by-project, "pondering" and "checklists" were the standard techniques used for risk identification whenever the task was undertaken. None of the standard techniques for quantifying risk likelihood or impacts or for pricing the risks into the estimates for the project were used. Instead, a percentage contingency sum is allowed for in the contract to cover economic risks while the contractor makes an allowance in his profit mark-up to cover all other risks for which he then obtains either general project or specific risk insurance.

It is evident from the results that there is a significant gap between the techniques available to the construction industry and what are actually used in the management of contractual risks. Contractual risks by their nature make it highly unlikely that one individual will have sufficient first hand experience of each risk to enable him/her conduct accurate and thorough identification and analysis of such risks in any major construction project, without making the whole risk management exercise heavily subject to the errors caused by personal biases and perceptions. This argument is supported by the fact that although 160 professionals were selected in the UK based on at least 10 years of industrial experience to participate in the study, only 29 felt they had sufficient experience to enable them respond to the survey questions. Yet the predominant practices in the industry seem to centre on one individual dealing with risk management and using techniques that are the most subject to personal perception biases and which do not consider the full range of outcomes of the risks.

6.2.2 Risk perception in construction and its impact on project performance

Although previous works identify experts as having better-developed mental problem representations, the study found that differences in individual perceptions among experts about risks result in differences in their estimates about the same risks, and that differing socio-cultural backgrounds of risk experts lead to significant differences in their estimates the same risks. However, the direction of the differences that the study found was contrary to expectations. General observations from the study in the UK reveal that on average less frequent risks are consistently overestimated while the more frequent risks are underestimated by the experts. Similarly, the impacts of low-impact risks were overestimated while those of more higher-impact risks were underestimated. These misjudgements are illustrative of the use of the "availability" heuristic in which events that are easier to imagine or recall are judged as relatively more frequent. The study also revealed that experts with recent experiences of the risks (i.e. experienced the risk(s) within the preceding twelve months) generally overestimated the risks while experts no recent experience of the risk(s) (i.e. the most recent experience of the risk(s) was more than twelve months old) generally underestimated the risks. Exceptions to these general patterns seem to be that experts with optimistic attitudes consistently gave lower estimates for risks despite their prior experiences, while pessimistic experts generally overestimated risks in spite of their lack of recent experience of the risks.

Perceptions are born out of ones knowledge, experiences and attitudes. The fact that all the respondents were experienced "experts" assumes a basic level of authority in their field. The observations about the estimating behaviours of the experts therefore only go to confirm the assertion that in spite of expertise, differences in individual perceptions about risks lead to differences in their estimates about the same risks.

Contrary to all expectations based on the literature (Cullivan, 1981) and the author's experience of the bidding prices of UK contractors for international projects, UK experts generally tended to give lower estimate of risk attributes than Ghana experts did. The only exceptions to this general pattern are that UK experts give higher estimates for the minimum number of occurrence of the risks, and the minimum and maximum impact of risks than Ghana experts do. This reveals a tendency among the UK experts to be concerned mainly with either their perception of the minimum and maximum values of the occurrence of risks and impact of the risks should they occur, or their perception of the financial premium they will need to pay to mitigate the risk. On the other hand, the Ghanaian contractors seem to demonstrate over-confidence towards mitigating the risks should they occur and therefore do not price the risk in accordance with their perception of the likelihood and impact of the risk. This seeming "overconfidence" which is widespread among Ghanaian contractors arise out of the culture among local contractors in Ghana to do whatever they need to do not only to win contracts, but to also keep within the "good books" of the government by working with the government to ensure successful projects in spite of defaults by the government and other risks. The culture among foreign experts currently working in Ghana tended to be adversarial.

6.2.3 Developing a model for eliciting quantified opinions about contractual risks

From the analysis of the literature, the study successfully developed a model for eliciting expert opinions about risks that minimises the adverse effects of risk perception, and that provides these opinions as an input variable to the systematic and effective analysis of contractual risks. The 3-phase model involved *Preliminaries* (process preparation, problem definition, elicitation schedule/question development and expert selection), *Expert Elicitation* (appointments for elicitation and formulation or encoding of expert estimates) and *Analysis* (assigning of numerical probability values to individual expert judgements and assigning of numerical probability values to aggregate expert judgements).

While testing and validating the model in the UK, the study confirmed the difficulty encountered by construction professionals in estimating intermediate and tail values of a probability distribution (Chapman & Ward, 1997). The findings however, did not support the use of the triangular distribution for contractual risk analysis. The study also revealed that although the probability values given by the probability density functions from the various categories differ from each other, the shapes of the curves are fairly similar to each other, indicating that the general problem representations for the risk among the experts are very similar, the differences arising perhaps because of differences in their experiences regarding the extremes of the occurrences. This finding supports the use of aggregation of expert opinions to capture a problem representation that truly reflects the collective knowledge and experience of the experts and therefore minimizes individual perception. The use of the "relative likelihood" approach to elicitation yielded more accurate results than the continuous variable scaling technique used to elicit the same estimates. The application of the model in Ghana revealed further that experts were more accurate in assigning their estimates about risks if they deal with only one risk at a time.

The effective capturing of the problem representations of the two groups of experts from Ghana and the UK by the elicitation model, and the ability of the questioning and response methods to enable most of the experts to self-elicit their own beliefs and transform them into probability representations are very powerful confirmations of the effectiveness of the elicitation model in an international context. By assigning numerical probability values to both individual and aggregate expert judgements about risks, the study was also able to derive the prior probability density functions for the likelihood and impact of risks. Coupled with the sample evidence that the survey collected, the study thus obtained all the essential components need to conduct a Bayesian analysis of contractual risks.

6.3 Main Conclusion of the Study

The main conclusion of the study is that contrary to the belief and practices that suggest that rigorous and probabilistic approaches and techniques could not be applied to the management of contractual risks, contractual risks in construction lend themselves very well to the types of rigorous and probabilistic analyses that are applied to similar risks in other industries. The current approaches and techniques for managing contractual risks are neither sufficiently appropriate nor rigorous enough for the nature of most construction contract risks, and give a false sense of security for project outcomes.

Although the use of standard forms of contracts which allocate standard contractual risks to the project parties is necessary and useful in establishing contractual relationships and defining obvious or standard risks in most projects, for major construction projects it is necessary to go past the contract into the project to analyse all what could go wrong on the project at a decomposed level, and to analyse what their impacts could on project outcomes in order to plan and price appropriate responses. Thus, the single and arbitrary percentage cost contingency often used by contractors to give an overall impression of their perception of the total risks that they are asked to carry is a rather poor attempt at managing construction risks as it directs attention away from other project risk targets such as project duration and quality, thereby giving a false sense of security for project outcomes. So are the Individual Expert Assessment approaches (whether In-house or external) commonly used in the industry for identifying and analysing risks on construction projects. Modern advancements in product, component and construction technologies, coupled with complex arrays of macro and market factors that impact on the project, have created such myriad specialisations in the industry that it is almost a joke to think that one expert can go solo on identifying and analysing all relevant risks on a major international project. Quite apart from the potential for failing to identify and analyse key project risks, such approaches are the most susceptible to the impact of personal biases and perceptions on expert estimates.

As to the assertions about the extra cost of pursuing a rigorous and systematic process, and the implication that such analyses can only be performed by larger companies, the study found evidence to the contrary. Most of the experts who used the probabilistic techniques in risk analysis were comparatively smaller companies with annual turnovers of less than £5 million. Furthermore, much of the analysis of the survey data used to derive the probability density functions of expert judgements which could then be used as input variables in a probabilistic analysis of risks were done using Microsoft Excel®, a software programme that most companies would have on their computing systems. This study has been able to develop an elicitation model for eliciting and encoding expert judgement about construction contract risks, and transforming these judgements into probability distributions that can be used as input variables in the Bayesian analysis of contractual risks in both local and international contexts. In the process of developing and testing this model, the study has also brought to light those existing risk management approaches and techniques that are the most suitable for contractual risks analysis in construction, and some of the flaws in current thinking and practice that need to be discarded. These provide new and valuable insights and tools that should enhance risk management effort within the construction industry, and guidance for future training and research in risk management. The processes and costs involved in applying this model in any corporate setting would be minimal, and will pale in comparison to the costs of the efficient systems currently being used in the industry. For example, in the seventeen out of the thirty-one sample projects that had project delays and on which percentage contingency sums were used as a measure of total risk, the average adverse impact of the delays on contractors' profits, project duration and project costs were as high as 35%, 57% and 48% respectively. Rigorous analyses using the team approaches and elicitation model developed through this study would have highlighted such a sensitive risk source and adopted appropriate responses and pricing.

Although the study focused on a relatively small sample of the total population of construction professionals in Ghana and the UK, the author argues that these findings can be generalised statistically for both Ghana and the UK for a number of reasons. First, the survey initially sampled randomly from the population of experts in each country without regard to the geographical location of the expert in the country. In Ghana, the study surveyed sampled from all the construction and consulting firms whose areas of expertise were relevant to the research. In the UK, equal and statistically representative numbers of participants from each applicable profession were selected. Secondly, the final target samples were those who had sufficient experience to be able deal with the variable in question. Thus, for example, the respondent size of 29 from the UK who felt they had sufficient experience to enable them respond to the survey questions (out of the 160 random sample of construction professionals) is a true reflection of the population of construction experts in the UK who have sufficient experience to provide expert estimates about risks. Also, evidence from previous research (Ashton & Ashton, 1985) indicate that much of the total gain in expert forecast accuracy attributable to aggregation of expert judgements can be achieved by combining a small number of individual estimates. The results of the study thus demonstrate the practicality of the model for use within most companies.

The past decade and a half has witnessed the liberalisation and restructuring of many developing economies, usually under the auspices of the International Monetary Fund (IMF) and the World Bank. With a population of about 16 million, a GDP of $5906 million and GNP of $7117 million (1993), Ghana was once cited by the World Bank and the IMF as a model of success in the developing countries (West Africa, 1995). As a former British colony, Ghana's legal, professional and economic systems are similar to what pertains in many commonwealth countries such as Nigeria. These patterns of commonalities leads the author to believe that construction practices seen in Ghana will closely match what pertains in many developing countries, especially among commonwealth countries, making the findings from the Ghana survey analytically relevant to other developing economies. So are the findings from the UK survey to other developed economies. For, example the findings of the study are consistent with the findings of Burchett *et al.* (1999)'s worldwide survey of risk management practices among electrical supply companies. A similar survey on contractors' approaches to risk identification in Australia (Bajaj *et. al.*, 1997), also found results consistent with the findings from the present UK study. The results of this study therefore offer insights and a contractual risk analysis approach that have wider international application.

6.4 Limitations of the Study

In Chapter 4 attention was drawn to aspects of the research design and data which could impose some limitations on the study and the efforts made to counter their effects on the validity and reliability of the findings. The following are further limitations that need to be highlighted in order that the findings can be appreciated in the appropriate context.

(a) *Validity of expert the estimates*: Throughout the analysis it has been assumed that all the estimates that the survey generated were indeed given by the expert to whom the survey instrument was sent. While this can be ascertained for those experts from whom the estimates were obtained through an interview, the same cannot be guaranteed regarding those estimates obtained by the self-elicitation of the expert. Estimates by non-experts or guesstimates from respondents could distort the results. In the practical application of the research findings however, this will not be an issue as the elicitation will be conducted for a specific project by a company that has a vested interest in the accuracy and validity of the results.

(b) *Data employed in analysis*: While the data generated was sufficient to demonstrate the achievement of the objectives of the research, the lack of a larger data set has blunted some of the analysis and conclusions that could be of further research interest. For example a larger data set on the projects with delays could allow the Bayesian analysis of the risk of project delay using a Monte Carlo simulation approach. As explained in Chapter 5 however, the lack of large and useable sets of data is neither the result of the nature of the survey instruments or approaches used nor the result of lack of effort. Based on the consistency of the findings of the some aspects of the current research with previous research in related areas (such as the use of risk management techniques), it is the author's belief that a larger data set would not necessarily produce a significantly different set of findings from the research.

(c) *Research Design*: It is possible that some of the findings of the research are specific to Ghana and the UK. As explained earlier however, many of the findings could apply to many developing and developed countries. Further research is needed on this basis. It is the strong belief of the author based on the successful application of the elicitation and analytical approach developed by the research in both the UK and Ghana, that such a model could be applied across different cultures irrespective of the state of the economic development of that country.

6.5 Recommendations for professional practice and further research

A number of implications for current professional practices and risk management training and research flow from the above conclusions and limitations. The following recommendations can therefore be made.

6.5.1 Recommendations for professional practice

The current practice of relying on one expert for risk identification and analysis tasks are inappropriate for contractual risks. In most consulting firms, an in-house team approach could be adopted by involving more experts at least at the project planning stages.

Among contractors, this could be achieved by creating a team involving both office and site staff at various stages of the project. Where necessary, the firm should be willing to obtain other external consulting assistance as appropriate for the risk management exercise. One problem is that for most contract bidding, risk analysis by the contractor is would need to be done prior to bidding and this will be at the contractor's expense. However, in the bidding systems where potential bidders are pre-qualified before being asked to bid, the cost of an effective analysis of risk for the ultimate optimum performance of the project could be partly borne by the client. For negotiated contracts, a team made up o experts from both the client team and the contractor's team would be most suitable. In essence, this calls for greater levels of integration and cooperation between the client and contracting teams and contractual arrangements that foster such cooperation at the project planning stages.

The immediate application of the elicitation and analytical approach developed in this study is also highly recommended for the industry. The benefits of applying such a system have been discussed in the previous sections. This approach will also reduce the need to rely on the triangular distribution function for risk analysis.

Perhaps one of the fundamental reasons for the lack of use of most of the rigorous approaches to risk analysis stems from the lack of training in these approaches in formal construction education programmes. A re-assessment of the training needs of the industry with regards to risk management is therefore required in order to establish how best to incorporate such training in formal construction education programmes.

6.5.2 Areas for further research

Better knowledge of many aspects of contractual risk management not directly investigated in this study will enhance the effectiveness of the recommendations for professional practice and risk management training. In this regard research in the following areas is considered essential.

(a) *Studies based in other countries*: As mentioned earlier, it is possible that some aspects of the research findings are specific to the two countries used as case studies. Further research in other countries or economies employing similar methodology applied in this study will be helpful in gaining a fuller understanding of the nature of risk management in international construction.

(b) *Application of the elicitation model to a complete set of project risks*: The elicitation model developed and successfully applied in this study was found to be effective when used to elicit attributes about a single risk. The average international construction project will involve numerous contractual risks. It is helpful to assess the effectiveness and impact of using the model to elicit expert judgements for all the key contractual risks that will need analysis in a complete project.

(c) Development of an elicitation software programme: To ease analysis of risks when the elicitation approach is applied to a complete set of project risks, research into developing a software programme that will automatically derive probability distributions from entries of expert judgements will be helpful. Such software could be a simple programme either based on a set of "macros" in Microsoft Excel (or similar programme) or developed as an add-in to a main programme.

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APPENDIX 1

EXPERT SELECTION - INITIAL PREQUALIFICATION LETTER AND SCHEDULE

THE UNIVERSITY OF EDINBURGH

DEPARTMENT *of* BUSINESS STUDIES

The University of Edinburgh
William Robertson Building
50 George Square
Edinburgh EH8 9JY

Fax 0131 668 3053
Telex 727442 (UNIVED G)
Telephone 0131 650 1000
or direct dial 0131 650 3067

(Date) Ref: RMP/JA/FKA-01

Dear Sir/Madam

Managing Contractual Risks for Optimum Performance and Profitability
'If anything can go wrong, it will go wrong.' - Murphy's Law

Over time, many of the things that we do not like to see go wrong on construction projects do actually go wrong! How well one is able to make the client aware of this and manage these 'risks' in ways that ensure the optimum project performance, reduction in conflict and the profitability of the contractor is something that is of utmost concern and interest. This is even more so when British contractors have to compete overseas. Recent EPSRC-sponsored studies indicate that estimates for risks on overseas project make up about 60% of the bid prices of most British contractors! Methods that enable consultants and contractors to efficiently identify, estimate and manage risks in construction can thus only help to enhance the competitiveness and profitability of British firms, and increase project performance.

The potential benefits of such methods have caused the Economic and Social Research Council to fund a 3-year research project based at the University of Edinburgh to investigate the development of a workable approach to contractual risk management, particularly within overseas projects. Recent advances in technology mean that the development of such a method is now possible, "with a little help from industrial experts". The project is being supervised by Dr Jake Ansell, FSS CSTAT, Associate Dean & Senior Lecturer in Operations Research and Statistics at the Department of Business Studies.

Given your organisation's role in the construction industry and your own professional standing and years of experience in the industry, we would appreciate if you were able to participate in the project by offering your expert opinions on some of the things that go wrong on construction projects. These opinions will be obtained either by phone or by a questionnaire none of which would take more than 25-35 minutes of your time. All information provided will be treated with the strictest confidence, and participants will be given an executive summary of the project report free of charge. If you are willing to participate in this project, would you please complete and fax/post the attached form to me within the next day or two, and we shall send you further details.

Thank you for your time, and I look forward to hearing from you soon.

Yours faithfully

F. K. Adams

Appendix 1 *(Continued)*

CONTRACTUAL RISK MANAGEMENT PROJECT

Thank you for your willingness to participate in the above project and offer your expert opinions regarding contractual risks in construction. All the information you provide to assist the research will be treated with the strictest confidence, and if you so desire, you would be given a free copy of the executive summary of the both the interim and final reports of the study.

Please complete the details below and return this form by fax or post in the next day or two, and we shall forward further details on the project to you shortly. Please send the form to:

Francis K. Adams
Department of Business Studies o University of Edinburgh
Fax: 0131 668 3053

CONTACT DETAILS

Name [ ]

Profession: ❑ Construction/Project Manager

❑ Quantity Surveyor ❑ Contracts Mgr.

❑ Other [ ]

Company [ ]

Address [ ]

[ ]

Town/City [ ]

Post code [ ]

Telephone [ ]

Fax [ ]

Average Turnover of Company (last 3-5 years)

(To the nearest £ m) [ ]

AREA(S) OF EXPERTISE

1.0 Nature of Business *(please tick as appropriate)*

- ❑ Building Contracting
- ❑ Civil Engineering Contracting
- ❑ Property Development
- ❑ Quantity Surveying/Cost Consulting
- ❑ Project Management Consulting
- ❑ Legal/Construction Contracts Consulting
- ❑ Other [ ]

2.0 Type of Work *(please tick your top 2)*

- ❑ Commercial/Industrial Buildings
- ❑ Public/Community Buildings
- ❑ Road/Civil Engineering Construction
- ❑ Other [ ]

3.0 Years of Experience *(please approximate)*

(a) In the Construction Industry [ ]

(b) In your current profession [ ]

COMMENTS

Please feel free to use this space to make any preliminary comments about the project and/or your involvement with it.

APPENDIX 2

PILOT SUVEY QUESTIONNAIRE

DEPARTMENT *of* BUSINESS STUDIES

CONTRACTUAL RISK MANAGEMENT PROJECT

INTERVIEW AND QUESTIONNAIRE SCHEDULE

INTRODUCTION

This questionnaire aims to find your opinions on how the things that can go wrong in a construction contract (contractual risks) are managed. In particular, it seeks to elicit your expert knowledge regarding the encountering of adverse ground conditions on a construction site. The description of the 'typical' site is provided at the appropriate section.

Your knowledge will be very helpful to us in our attempt to model contractual risks, and we would value the time spent in answering the questions in as much detail as you can. It would be particularly helpful if you could base your answers on your actual experience (rather than rules of thumb or general theories). If you find it helpful, please feel free to consult colleagues or other sources of expert opinion in formulating your answers. Obviously, if at any time you wish to change an answer you had given previously after giving it further thought, please feel free to do so.

The questionnaire is designed to be able to elicit your knowledge on the issues it raises, so any comments on the clarity and/or simplicity of the questions are most welcome. Explanations of some of the terms used in the schedule are provide at the back of the schedule, but please feel free to phone and ask for any further explanation that you may require regarding any question, and we will be delighted to provide all the needed explanations.

When phoning, please contact: Francis K. Adams
Tel: 0131-650 3067
Fax: 0131-668 3053
e-mail: Francis.K.Adams@ed.ac.uk

Alternatively, you may contact: Dr. Jake Ansell
Tel: 0131-650 3806
Fax: 0131-668 3053
e-mail: J.Ansell@ed.ac.uk

Thank you for your cooperation and assistance with the study.

Appendix 2 *(Continued)*

SECTION 1: PERSONAL DETAILS

Name ☐ Title (Mr/Miss/Mrs/Dr, etc) ☐

Company

Address

Town/City Post code

Telephone Fax

SECTION 2: AREA(S) OF EXPERTISE

1.0 Profession/Job Title/Job Function (please tick (✓) only the most applicable one)

- ☐ Construction Manager
- ☐ Project Manager
- ☐ Quantity Surveyor
- ☐ Contracts Manager
- ☐ Other (please specify)

2.0 Approximate Number of Years of Experience

(a) In the Construction Industry

(b) In your current profession

3.0 Nature of Business (please tick (✓) as applicable)

- ☐ Building Contracting
- ☐ Civil Engineering Contracting
- ☐ Property Development
- ☐ Project Management Consulting
- ☐ Quantity Surveying/Cost Consulting
- ☐ Legal/Contracts Consulting
- ☐ Other (please specify)

4.0 Type(s) of Work Normally Undertaken (please tick (✓) your top 2)

- ☐ Commercial/Industrial Buildings
- ☐ Public/Community Buildings
- ☐ Road/Civil Engineering Construction
- ☐ Other

5.0 Average Annual Turnover (please tick (✓) as applicable)

☐ Under £1m ☐ £1m - £5m ☐ £6m - £25m ☐ £26 - £50m ☐ Over £50m

SECTION 3: TECHNIQUES FOR ASSESSING THINGS THAT CAN GO WRONG

1.0 By what means are assessments of contract risks normally made in your current company *(please tick (✓) as many as apply):*

- ☐ In-house Individual
- ☐ In-house Synectic Team
- ☐ In-house Multi-disciplinary Group
- ☐ Other:

2.0 In seeking to identify things that can go wrong (risks) on a project, how often do you use the following techniques *(please tick (✓) for those that apply):*

	Always	Very Frequently	Frequently	Occasionally	Never
Pondering					
Brainstorming					
Synectics					
Checklists					
Risk Records					
Prompt Lists					
Expert Interviews					
Other *(please specify)*					

3.0 In assessing how likely any identified risks are to actually occur on a project, how often do you use the following techniques *(please tick (✓) those that apply):*

	Always	Very Frequently	Frequently	Occasionally	Never
Quantitative Probability Assessments based on Historical Data					
Subjective Probability Assessments based on Expert judgement					
Scaled Assessments (eg High ÷ Low) based on experience					
Other *(please specify):*					

4.0 In assessing the severity or consequences of a risk, how often do you use the following techniques (please tick (✔) for those that apply):

	Always	Very Frequently	Frequently	Occasionally	Never
Quantitative Assessments based on Historical Data					
Fresh Estimation of Actual severity should risk occur					
Scaled Assessments based on experience (eg High↔Low)					
Other (please specify)					

5.0 In seeking to quantify or assess the impact of the risks on a project, how often do you use the following analytical techniques (please tick (✔) for those that apply):

	Always	Very Frequently	Frequently	Occasionally	Never
Decision Trees Analysis					
Fault Trees Analysis					
Event Trees Analysis					
Probability Analysis					
Sensitivity Analysis					
Scenario Analysis					
Simulation Analysis					
Ranking Options					
Other (please specify):					

6.0 Please list in descending order the three contract risks whose effective management you consider most important to the performance of a project:

1	
2	
3	

SECTION 4: OCCURRENCES OF ADVERSE GROUND CONDITIONS

1.0 How many projects have you been directly involved with in the past 15 years?

☐ Under 5 ☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ Over 20

2.0 On how many of these did you have problems with adverse ground conditions?

☐ Under 5 ☐ 5-10 ☐ 11-15 ☐ 16-20 ☐ Over 20

3.0 How would you describe the principal soil types for your 5 most recent cases of projects with adverse ground conditions (please tick (✔) as appropriate)?

Project / Soil Type	1	2	3	4	5
Gravel					
Sand					
Clay					
Silt					
Organic Silt					
Peat					
Other					
(please specify)					

4.0 How would you describe the type of development for your 5 most recent cases of projects with adverse ground conditions (please tick (✔) as appropriate)?

Project / Development	1	2	3	4	5
New Development					
Redevelopment					
Repairs/Maintenance					
Other (please specify)					
Other (please specify)					

SECTION 5: EXPERT OPINIONS ON LIKELIHOODS

The questions in this section assumes the following project description as typical

The project comprise the erection of a ten-level reinforced concrete and structural steel frame office block development including demolition works, a basement car parking, reinforced concrete raft foundations, retaining walls and reinforced in-situ concrete frame of columns. The site is located in a busy commercial sector in a major city. It is currently occupied by an old and derelict warehouse that is marked for demolition, but has been used in the past for buildings of a similar nature as the warehouse. The land is of compact, dark grey, sub-angular, well-graded GRAVEL with little finer material and water level judged to be well below the designed maximum depth of foundations.

1.0 Assuming a 100 of such projects are to be constructed, what is the minimum number that you would expect to encounter adverse ground conditions?

2.0 What is the maximum number that you would expect to encounter adverse ground conditions among the 100 projects?

3.0 What is the most likely number that you would expect to encounter adverse ground conditions among the 100 projects? (call this number 'A')

A

4.0 If 'A' is the most likely number, and we assigned this number a proportional 'likelihood rating' of 60 units what, in your opinion, is the number, greater than 'A' that would be half as likely as 'A' to merit a likelihood rating of 30 units?

5.0 What number, smaller than 'A', of projects with adverse ground conditions would be half as likely as 'A' to merit a likelihood rating of 30 units?

6.0 What number, greater than 'A', of projects with adverse ground conditions would be a quarter as likely as 'A' to merit a likelihood rating of 15 units?

7.0 What number, smaller than 'A', of projects with adverse ground conditions would be a quarter as likely as 'A' to merit a likelihood rating of 15 units?

8.0 By use of a dot (•) on the scale on the next page (where 0 = Never and 1 = Certain), indicate how likely you feel there could be the indicated numbers of projects encountering adverse ground conditions among the 100 typical projects (Answers will be re-scaled to add up to 1).

No. of Projects	Likelihood				
	Never		Likely		Certainly
	0	.25	.50	.75	1
As few as 0					
As many as 5					
As many as 25					
As many as 50					
As many as 75					
As many as 95					
As many as 100					

SECTION 6: ADDITIONAL INFORMATION AND COMMENTS

Please use this page to provide any additional information on your responses or to comment on the research and this questionnaire (eg clarity and/or simplicity of the questions)

SECTION 6: ADDITIONAL INFORMATION AND COMMENTS (cont'd)

Thank you once again for your involvement in the research and for your contribution

IF YOU SO PREFER, YOU MAY POST YOUR COMPLETED SCHEDULE TO:

Francis K. Adams
Department of Business Studies • University of Edinburgh
William Robertson Building • 50 George Square
Edinburgh • EH8 9JY • Fax: 0131 668 3053

GLOSSARY

Pondering : *An individual carefully and critically considering a project or project activity to gain an insight into 'what can go wrong' on the project or project activity.*

Brainstorming : *Analysis of the risk problem from different points of view and over a period of time by a group of individuals with a variety of backgrounds who come together temporarily for that purpose.*

Synectics : *Analysis of the risk problem by a carefully selected team of highly qualified and equipped individuals who deal with organisation-specific problems on a full-time basis.*

Economic Risks : *Those things on which it is intended that costs be incurred, but for which uncertainties arise because they can assume any one of a range of potential values (costs) and therefore may involve someone specified by the contract in extra expenditure should the realised value be more than that initially agreed.*

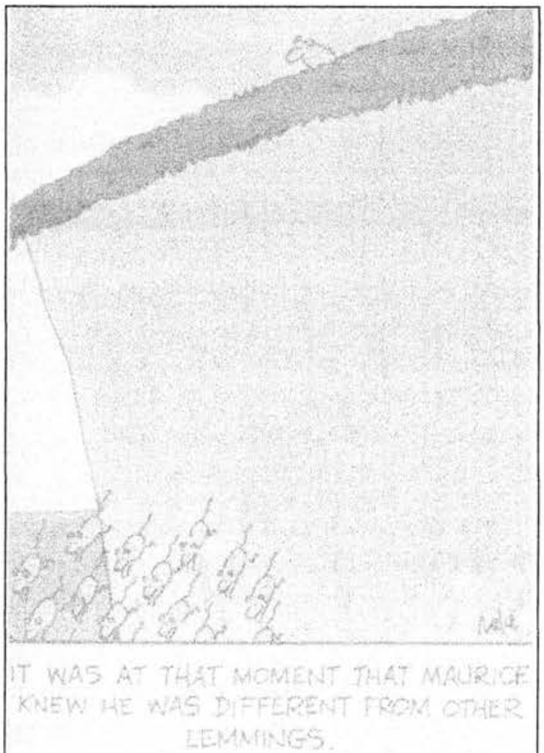
Contractual Risks: *The unexpected things that it is intended or hoped will not happen at all on the project and which, if they do happen, will then involve someone specified by the contract bearing the cost e.g. adverse ground conditions*

APPENDIX 3

QUESTIONNAIRE FOR THE RISK PERCEPTION SURVEY IN GHANA

DEPARTMENT *of* BUSINESS STUDIES

RISK MANAGEMENT RESEARCH PROJECT



RISK PERCEPTION SURVEY - 1998

INTRODUCTION

This questionnaire aims to find out your beliefs about some of the things that can go wrong in a construction project.

Your answers will be very helpful to us in our attempt to model contractual risks, and we would value the time spent in answering the questions in as much detail as you can. It would be particularly helpful if you could responses that reflect your actual beliefs, rather than any reported statistics.

The questionnaire is designed to be able to elicit your knowledge on the issues it raises, so any comments on the clarity and/or simplicity of the questions are most welcome. Please feel free to phone and ask for any further explanation that you may require regarding any question, and we will be delighted to provide all the explanations required.

When phoning, please contact:

Francis K. Adams
Tel.: 021-505 216
Fax: 021-505 216

When finished, please either
telephone Francis Adams on 021 505 216 to arrange collection, or
fax the questionnaire to 021 505 216, or
post it to:

Francis K. Adams
P. O. Box 9924
Kotoka International Airport
Accra

Thank you for your cooperation and assistance with the study.

SECTION 1: PROFESSIONAL PROFILE

1.0 Approximately how long you have been involved in

(a) the construction industry? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

(b) your current profession? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

2.0 Which <u>one</u> or <u>two</u> of the following best describe(s) the predominant nature of your professional experience?

- ❑ Building Contracting
- ❑ Civil Engineering Contracting
- ❑ Property Development
- ❑ Design Consulting
- ❑ Project Management Consulting
- ❑ Quantity Surveying/Cost Consulting
- ❑ Legal/Contracts Consulting
- ❑ Other (please specify): ....

3.0 Which <u>one</u> of the following best describes your present profession, job title or job function?

- ❑ Construction/Site Manager
- ❑ Project Manager
- ❑ Quantity Surveyor
- ❑ Contracts Manager
- ❑ Design Consultant
- ❑ Legal/Contracts Consultant
- ❑ Other (please specify): ....

4.0 (a) Do your job responsibilities include project risk assessment?

❑ Yes ❑ No

(b) If 'No', who in your company deals with project risk assessment?

(name/job title of individual): ....

5.0 (a) Have your various job responsibilities during the past 10 years included project risk assessments?

❑ Yes ❑ No

(b) If 'Yes', on what percentage of projects during the past 10 years have you had to prepare

i. Results of formal risk assessment? (approximately) .... %

ii. Measures to mitigate against risk effects? (approximately) .... %

iii. Acceptable Risk premiums for bidding purposes? (approximately) .... %

iv. Fall-back options to recover programme/cost (approximately) .... %

6.0 How many of the following types of contracts have you been involved with in the past 10 years?

(a) international (overseas) projects, generally ? (approximately) ....

(b) projects based in <u>developed</u> countries? (approximately) ....

(c) projects based in sub-Saharan Africa? (approximately) ....

(d) projects based in Ghana? (approximately) ....

7.0 What is the average Annual Turnover of your company (please tick (✓) as applicable)

❑ Under £5m ❑ £6m - £25m ❑ £26 - £50m ❑ Over £50m ❑ Unable to divulge

Appendix 3 (*Continued)*

SECTION 2: OCCURRENCES OF CONSTRUCTION ACCIDENTS

The aim of this section is to obtain your beliefs and experiences about how frequently certain construction-related accidents occur. A normal year is one in which you will consider that the numbers and types of accidents which occur are reflective of the general annual levels of accidents in the construction industry. A disastrous year is one in which you will consider that the numbers and types of accidents which occur are the highest or worst in say a 10-year period.

1.0 Assuming this year is a normal year for construction in Ghana, what is the total number of accidents that you believe would result from the following causes, and how many of these accidents would be fatal?

	Cause of Accident	Anticipated total Number of accidents	Anticipated Number of fatal accidents
a	Contact with moving machinery or material being machined		
b	Struck by moving a object (including a moving vehicle)		
c	Strike against something fixed or stationary		
d	Injured whilst handling, lifting or carrying		
e	Fall from a height		
f	Trapped by something collapsing or overturning		
g	Exposure to or contact with harmful substance		
i	Exposure to an explosion		
j	Contact with electricity or an electrical discharge		

2.0 Assuming this year is a disastrous year for construction in Ghana, what is the total number of accidents that you believe would result from the following causes, and how many of these accidents would be fatal?

	Cause of Accident	Anticipated total Number of accidents	Anticipated Number of fatal accidents
a	Contact with moving machinery or material being machined		
b	Struck by moving a object (including a moving vehicle)		
c	Strike against something fixed or stationary		
d	Injured whilst handling, lifting or carrying		
e	Fall from a height		
f	Trapped by something collapsing or overturning		
g	Exposure to or contact with harmful substance		
i	Exposure to an explosion		
j	Contact with electricity or an electrical discharge		

3.0 How many times have you encountered any of the following accidents in the past 12 months?

		Frequency of Encounter (please tick (✓))					
	Cause of Accident	None	1-5	6-10	11-15	16-20	Over 20
a	Contact with moving machinery or material being machined						
b	Struck by moving a object (including a moving vehicle)						
c	Strike against something fixed or stationary						
d	Injured whilst handling, lifting or carrying						
e	Fall from a height						
f	Trapped by something collapsing or overturning						
g	Exposure to or contact with harmful substance						
i	Exposure to an explosion						
j	Contact with electricity or an electrical discharge						

Appendix 3 (*Continued*)

4.0 Approximately how long ago did you last encounter/hear of any of the following accidents and, was it fatal?

		Period since last encounter of accident (in months)					Was it fatal?	
	Cause of Accident	1	3	6	12	Over 12	Yes	No
a	Contact with moving machinery or material being machined							
b	Struck by moving a object (including a moving vehicle)							
c	Strike against something fixed or stationary							
d	Injured whilst handling, lifting or carrying							
e	Fall from a height							
f	Trapped by something collapsing or overturning							
g	Exposure to or contact with harmful substance							
i	Exposure to an explosion							
j	Contact with electricity or an electrical discharge							

5.0 Would you be willing to provide feedback on this questionnaire when contacted? ☐ Yes ☐ No

If 'Yes', please either complete your details below or attach your business card so we may be able to contact you.

Title: .... First Name(s): .... Surname: ....

Job Title: ....

Company: ....

Contact Address: ....

Contact Telephone: .... Fax: ....

Thank you very much for your contribution.

Please either telephone Francis Adams on 021 505 216 to arrange collection,

or fax the questionnaire to 021 505 216, or post it to:

Francis K. Adams (RM) • P. O. Box 9924 • Kotoka International Airport • Accra

APPENDIX 4

QUESTIONNAIRE FOR THE RISK LIKELIHOOD AND IMPACT SURVEY IN GHANA

DEPARTMENT *of* BUSINESS STUDIES

RISK MANAGEMENT RESEARCH PROJECT

RISK LIKELIHOOD AND IMPACT SURVEY - 1998

INTRODUCTION

This questionnaire aims to elicit your opinions on how the things that can go wrong in a construction contract (contractual risks) are managed. In particular, it seeks to elicit your expert knowledge regarding the likelihood of occurrence and impact of certain risks that affect international contracts, particularly those based in developing countries. The description of a 'typical' project is provided to enable you to put your responses in a context.

Your knowledge will be very helpful to us in our attempt to model contractual risks, and we would value the time spent in answering the questions in as much detail as you can. It would be particularly helpful if you could base your answers on your actual experience rather than rules of thumb or general theories. If you find it helpful, please feel free to consult colleagues or other sources of expert opinion in formulating your answers. Obviously, if at any time you wish to change an answer you had given previously after giving it further thought, please feel free to do so.

The questionnaire is designed to be able to elicit your knowledge on the issues it raises, so any comments on the clarity and/or simplicity of the questions are most welcome. Please feel free to phone and ask for any further explanation that you may require regarding any question, and we will be delighted to provide all the explanations required.

When phoning, please contact:

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post it to:

Francis K. Adams
P. O. Box 9924
Kotoka International Airport
Accra

Thank you for your cooperation and assistance with the study.

SECTION 1: RELATIVE LIKELIHOODS OF OCCURRENCES OF RISKS IN INTERNATIONAL CONSTRUCTION CONTRACTS

The questions in this questionnaire assume the following project description as typical. Make any other assumptions the way you normally would in estimating for risks in the absence of fully detailed information. Your responses should relate to levels of risk that are at least significant enough to merit your attention.

The project is a 400 mile (644 km)-long highway from Accra, to one of the new cities in the northern part of Ghana. This route which passes through mainly rural areas, is mostly a poor gravel road and is to be re-constructed to a two-lane bituminous paved standard. It will be the main access route from this new city and the surrounding villages to the capital. The client is the Government of Ghana, but the project is being financed by the World Bank

1.0 For each of the following undesired project risks, what estimate would you consider to be the minimum number of times that the risk, taken on its on, can materialise among a 100 of such projects?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

2.0 What estimate would you consider to be the maximum number of times that the risk, taken on its own, can materialise among a 100 of such projects?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

3.0 What estimate would you consider to be the most likely number of times that the risk, taken on its on, can materialise among a 100 of such projects ? (Let's call this number 'A')

i. delay in project completion caused by client : .... (A)
ii. delays in payment by client : .... (A)
iii. exchange rate movements : .... (A)
iv. disputes or personality/cultural clashes : .... (A)

4.0 If 'A' is the most likely number for the risk , and we assigned this number a proportional 'likelihood rating' of 60 units, what estimate greater than 'A' would you consider to be half as likely to materialise as 'A' (i.e. have a likelihood rating of 30 units)?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

5.0 What estimate smaller than 'A' would you consider to be also half as likely to materialise as 'A' (i.e. have a likelihood rating of 30 units)?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

6.0 What estimate <u>greater than</u> 'A' would you consider to be a quarter as likely to materialise as 'A' (i.e. have a likelihood rating of 15 units)?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

7.0 What estimate <u>smaller than</u> 'A' would you consider to be also a quarter as likely to materialise as 'A' (i.e. have a likelihood rating of 15 units)?

i. delay in project completion caused by client : ....
ii. delays in payment by client : ....
iii. exchange rate movements : ....
iv. disputes or personality/cultural clashes : ....

SECTION 2: SEVERITY OF RISKS IN INTERNATIONAL CONSTRUCTION CONTRACTS

The questions in this section assume the following project description as typical. Make any other assumptions the way you normally would in estimating for risks in the absence of fully detailed information:

The project is a 400 mile (644 km)-long highway from Accra, to one of the new cities in the northern part of Ghana. This route which passes through mainly rural areas, is mostly a poor gravel road and is to be re-constructed to a two-lane bituminous paved standard. It will be the main access route from this new city and the surrounding villages to the capital. The client is the Government of Ghana, but the project is being financed by the World Bank

1.0 On a scale of 0-100 where 0 means 'No significant effect on project costs, duration or profits' and 100 means 'total loss of profits and/or a catastrophic escalation in project costs and/or duration', how would you estimate the <u>minimum</u> impact on the project (cost, duration and/or profits) by each of the following undesired project risks should they materialise?

	Cost	Duration	Profit
i. delay in project completion caused by client :	....	....	....
ii. delays in payment by client :	....	....	....
iii. exchange rate movements :	....	....	....
iv. disputes or personality/cultural clashes :	....	....	....

2.0 What estimate would you consider to be the <u>maximum</u> impact on the project (cost, duration and/or profits) by each of the following undesired project risks should they materialise?

	Cost	Duration	Profit
i. delay in project completion caused by client :	....	....	....
ii. delays in payment by client :	....	....	....
iii. exchange rate movements :	....	....	....
iv. disputes or personality/cultural clashes :	....	....	....

3.0 What estimate would you consider to be the <u>most likely</u> impact on the project (cost, duration and/or profits) by each of the following undesired project risks should they materialise? (call this number 'A')

		Cost	Duration	Profit
i.	delay in project completion caused by client :	....	....	....
ii.	delays in payment by client :	....	....	....
iii.	exchange rate movements :	....	....	....
iv.	disputes or personality/cultural clashes :	....	....	....

4.0 If 'A' is the most likely impact for each risk , and we assigned this level of impact a proportional 'severity units' of 60, what level of impact <u>greater than</u> 'A' would you consider to be half as likely to materialise as 'A' (i.e. have severity units of 30 units)?

		Cost	Duration	Profit
i.	delay in project completion caused by client :	....	....	....
ii.	delays in payment by client :	....	....	....
iii.	exchange rate movements :	....	....	....
iv.	disputes or personality/cultural clashes :	....	....	....

5.0 What level of impact <u>smaller than</u> 'A' would you consider to be half as likely to materialise as 'A' (i.e. have severity units of 30 units)?

		Cost	Duration	Profit
i.	delay in project completion caused by client :	....	....	....
ii.	delays in payment by client :	....	....	....
iii.	exchange rate movements :	....	....	....
iv.	disputes or personality/cultural clashes :	....	....	....

6.0 What level of impact <u>greater than</u> 'A' would you consider to be a quarter as likely to materialise as 'A' (i.e. have severity units of 15 units)?

		Cost	Duration	Profit
i.	delay in project completion caused by client :	....	....	....
ii.	delays in payment by client :	....	....	....
iii.	exchange rate movements :	....	....	....
iv.	disputes or personality/cultural clashes :	....	....	....

7.0 What level of impact <u>smaller than</u> 'A' would you consider to be also a quarter as likely to materialise as 'A' (i.e. have severity units of 15 units)?

		Cost	Duration	Profit
i.	delay in project completion caused by client :	....	....	....
ii.	delays in payment by client :	....	....	....
iii.	exchange rate movements :	....	....	....
iv.	disputes or personality/cultural clashes :	....	....	....

8.0 For each of the following risks, please indicate the approximate number of times you have encountered a significant level of the risk (i.e. significant enough to merit your attention or affect the project) on ICB (International Competitive Bidding) projects that have you been involved with in the past 10 years.

i. delay in project completion caused by client : ....

ii. delays in payment by client : ....

iii. exchange rate movements : ....

iv. disputes or personality/cultural clashes : ....

9.0 On a scale of 0-100 where 0 means 'No significant effect on project costs, duration or profits' and 100 means 'total loss of profits and/or a catastrophic escalation in project costs and/or duration', please indicate the impact of the risk(s) on the project (cost, duration and/or profit), for your most recent experience of the risk on an ICB (International Competitive Bidding) project.

	Impact of Risk on		
	Cost	Duration	Profit
i. delay in project completion caused by client :	....	....	....
ii. delays in payment by client :	....	....	....
iii. exchange rate movements :	....	....	....
iv. disputes or personality/cultural clashes :	....	....	....

SECTION 3: PAYMENT DELAYS

1.0 How many ICB projects have you been involved with in the past 10 years?
(approximately) ....

2.0 Approximately how many of these projects had the following as the primary source of funding?

Funding Source	No. of Projects
i. Local-Government	....
ii. Local-Private (Company/Individual)	....
iii. External (e.g. World Bank/IMF)	....
iv. Other Source (specify):	....

3.0 Please indicate on approximately how many of the projects with the following primary source of client-funding you encountered payment delays, and the average impact of the delays (on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'total lose or a catastrophic effect'):

Funding Source	No. of Projects	Average Impact
i. Local-Government	....	....
ii. Local-Private (Company/Individual)	....	....
iii. External (e.g. World Bank/IMF/Donor Country)	....	....
iv. Other Source (specify):	....	....

4.0 For your most recent experience of payment delays, please indicate on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'total lose or a catastrophic effect', the initial estimates made, if any, for the impact of the risk on the following attributes of the project:

i. level of contractor's profit ....
ii. level of conflicts ....
iii. project duration ....
iv. project cost ....

5.0 Please indicate, on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'total lose or a catastrophic effect', the approximate realised impact of the risk on the following attributes of the project for your most recent experience of payment delays:

i. level of contractor's profit ....
ii. level of conflicts ....
iii. project duration ....
iv. project cost ....

6.0 Please indicate the primary source of project funding for the two most recent occurrences of payment delays you have experienced (please tick (4) only one per project)

Funding Source	Project 1	Project 2
i. Local-Government	❑	❑
ii. Local-Private Client	❑	❑
iii. External (e.g. World Bank)	❑	❑
iv. Other Source:	❑	❑

7.0 (a) Would you be willing to provide feedback on this questionnaire when contacted? ❑ Yes ❑ No

(b) Would you be willing to make further contributions to the research when contacted? ❑ Yes ❑ No

If 'Yes', please either complete your details below or attach your business card so we may be able to contact you.

Title: .... First Name(s): .... Surname: ....

Job Title: ....

Company: ....

Contact Address: ....

Contact Telephone: .... Fax: ....

Thank you very much for your contribution.

Please either telephone Francis Adams on 021 505 216 to arrange collection,

or fax the questionnaire to 021 505 216, or post it to:

Francis K. Adams (RM) • P. O. Box 9924 • Kotoka International Airport • Accra

Risk Assessment Questionnaire • Department of Business Studies • University of Edinburgh Page 7 of 7

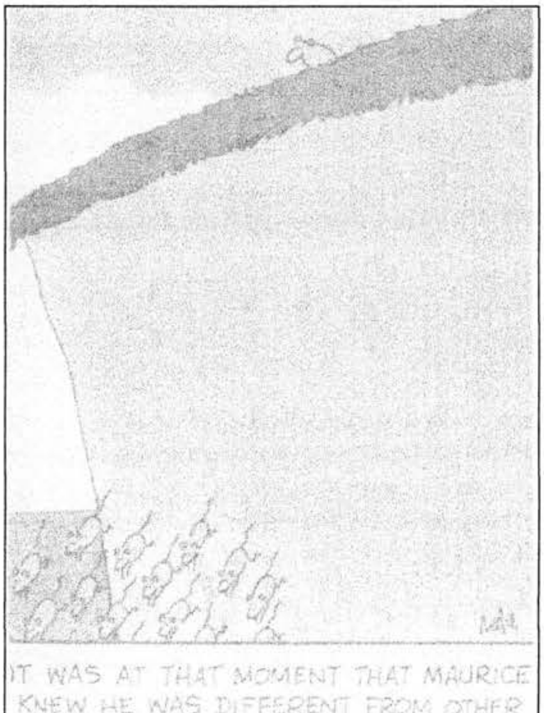
APPENDIX 5

QUESTIONNAIRE FOR THE RISK PERCEPTION SURVEY IN THE UK

THE UNIVERSITY OF EDINBURGH

DEPARTMENT *of* BUSINESS STUDIES

RISK MANAGEMENT RESEARCH PROJECT



RISK PERCEPTION SURVEY - 1998

INTRODUCTION

This questionnaire aims to find out your beliefs about some of the things that can go wrong in a construction project.

Your answers will be very helpful to us in our attempt to model contractual risks, and we would value the time spent in answering the questions in as much detail as you can. It would be particularly helpful if you could provide responses that reflect your actual beliefs, rather than any reported statistics.

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When finished, please either return it in the pre-paid envelope provided or fax it to:

Francis K. Adams
Department of Business Studies
University of Edinburgh
William Robertson Building
50 George Square
Edinburgh
EH8 9JY
Fax: 0131 668 3053

Thank you for your cooperation and assistance with the study.

SECTION 1: PROFESSIONAL PROFILE

1.0 Approximately how long you have been involved in

(a) the construction industry? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

(b) your current profession? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

2.0 Which <u>one</u> or <u>two</u> of the following best describe(s) the predominant nature of your professional experience?

❑ Building Contracting ❑ Civil Engineering Contracting

❑ Property Development ❑ Design Consulting

❑ Project Management Consulting ❑ Quantity Surveying/Cost Consulting

❑ Legal/Contracts Consulting ❑ Other (please specify): ....

3.0 Which <u>one</u> of the following best describes your present profession, job title or job function?

❑ Construction/Site Manager ❑ Project Manager

❑ Quantity Surveyor ❑ Contracts Manager

❑ Design Consultant ❑ Legal/Contracts Consultant

❑ Other (please specify): ....

4.0 (a) Do your job responsibilities include project risk assessment?

❑ Yes ❑ No

(b) If 'No', who in your company deals with project risk assessment?

(name/job title of individual): ....

5.0 (a) Have your various job responsibilities during the past 10 years included project risk assessments?

❑ Yes ❑ No

(b) If 'Yes', on what percentage of projects during the past 10 years have you had to prepare

i. Results of formal risk assessment? (approximately) .... %

ii. Measures to mitigate against risk effects? (approximately) .... %

iii. Acceptable Risk premiums for bidding purposes? (approximately) .... %

iv. Fall-back options to recover programme/cost (approximately) .... %

6.0 How many of the following types of contracts have you been involved with in the past 10 years?

(a) international (overseas) projects, generally ? (approximately) ....

(b) projects based in <u>developed</u> countries? (approximately) ....

(c) projects based in sub-Saharan Africa? (approximately) ....

(d) projects based in Ghana? (approximately) ....

7.0 What is the average Annual Turnover of your company (please tick (✓) as applicable)

❑ Under £5m ❑ £6m - £25m ❑ £26 - £50m ❑ Over £50m ❑ Unable to divulge

Appendix 5 *(Continued)*

SECTION 2: OCCURRENCES OF CONSTRUCTION ACCIDENTS

The aim of this section is to obtain your beliefs and experiences about how frequently certain construction-related accidents occur. A normal year is one in which you will consider that the numbers and types of accidents which occur are reflective of the general annual levels of accidents in the construction industry. A disastrous year is one in which you will consider that the numbers and types of accidents which occur are the highest or worst in say a 10-year period.

1.0 Assuming this year is a <u>normal year</u> for construction in Ghana, what is the <u>total</u> number of accidents that you believe would result from the following causes, and how many of these accidents would be fatal?

	Cause of Accident	Anticipated total Number of accidents	Anticipated Number of fatal accidents
a	Contact with moving machinery or material being machined		
b	Struck by moving a object (including a moving vehicle)		
c	Strike against something fixed or stationary		
d	Injured whilst handling, lifting or carrying		
e	Fall from a height		
f	Trapped by something collapsing or overturning		
g	Exposure to or contact with harmful substance		
i	Exposure to an explosion		
j	Contact with electricity or an electrical discharge		

2.0 Assuming this year is a <u>disastrous year</u> for construction in Ghana, what is the <u>total</u> number of accidents that you believe would result from the following causes, and how many of these accidents would be fatal?

	Cause of Accident	Anticipated total Number of accidents	Anticipated Number of fatal accidents
a	Contact with moving machinery or material being machined		
b	Struck by moving a object (including a moving vehicle)		
c	Strike against something fixed or stationary		
d	Injured whilst handling, lifting or carrying		
e	Fall from a height		
f	Trapped by something collapsing or overturning		
g	Exposure to or contact with harmful substance		
i	Exposure to an explosion		
j	Contact with electricity or an electrical discharge		

3.0 How many times have you encountered any of the following accidents in the past 12 months?

		Frequency of Encounter (please tick (✓))					
	Cause of Accident	None	1-5	6-10	11-15	16-20	Over 20
a	Contact with moving machinery or material being machined						
b	Struck by moving a object (including a moving vehicle)						
c	Strike against something fixed or stationary						
d	Injured whilst handling, lifting or carrying						
e	Fall from a height						
f	Trapped by something collapsing or overturning						
g	Exposure to or contact with harmful substance						
i	Exposure to an explosion						
j	Contact with electricity or an electrical discharge						

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4.0 Approximately how long ago did you last encounter/hear of any of the following accidents and, was it fatal?

	Cause of Accident	Period since last encounter of accident (in months)					Was it fatal?	
		1	3	6	12	Over 12	Yes	No
a	Contact with moving machinery or material being machined							
b	Struck by moving a object (including a moving vehicle)							
c	Strike against something fixed or stationary							
d	Injured whilst handling, lifting or carrying							
e	Fall from a height							
f	Trapped by something collapsing or overturning							
g	Exposure to or contact with harmful substance							
i	Exposure to an explosion							
j	Contact with electricity or an electrical discharge							

5.0 Assuming this is a <u>normal year</u> for construction in <u>a developing country like Ghana</u>, what is the <u>total</u> number of accidents that you believe would result from the following causes, and how many of the accidents would be fatal?

	Cause of Accident	Anticipated total Number of accidents	Anticipated Number of fatal accidents
a	Contact with moving machinery or material being machined		
b	Struck by moving a object (including a moving vehicle)		
c	Strike against something fixed or stationary		
d	Injured whilst handling, lifting or carrying		
e	Fall from a height		
f	Trapped by something collapsing or overturning		
g	Exposure to or contact with harmful substance		
i	Exposure to an explosion		
j	Contact with electricity or an electrical discharge		

6.0 Approximately how long ago did you last encounter/hear of any of the following accidents in Ghana or a developing country and, was it fatal?

	Cause of Accident	Period since last encounter of accident (in months)					Was it fatal?	
		1	3	6	12	Over 12	Yes	No
a	Contact with moving machinery or material being machined							
b	Struck by moving a object (including a moving vehicle)							
c	Strike against something fixed or stationary							
d	Injured whilst handling, lifting or carrying							
e	Fall from a height							
f	Trapped by something collapsing or overturning							
g	Exposure to or contact with harmful substance							
i	Exposure to an explosion							
j	Contact with electricity or an electrical discharge							

7.0 Would you be willing to provide feedback on this questionnaire when contacted? ☐ Yes ☐ No
If 'Yes', please attach your business card so we may be able to contact you.

Thank you very much for your contribution.

Please either return it in the pre-paid envelope provided or fax it to:

Francis K. Adams (RM001)• Department of Business Studies • Fax: 0131 668 3053

APPENDIX 6

QUESTIONNAIRE FOR THE RISK LIKELIHOOD AND IMPACT SURVEY IN THE UK

DEPARTMENT *of* BUSINESS STUDIES

RISK MANAGEMENT RESEARCH PROJECT

RISK LIKELIHOOD AND IMPACT SURVEY - 1998

INTRODUCTION

This questionnaire aims to elicit your opinions on how the things that can go wrong in a construction contract affect the performance of a construction project. In particular, it seeks to elicit your expert knowledge regarding the likelihood of occurrence and impact of the risk of payment delays by construction project clients, especially for international projects based in developing countries. For the purposes of the study a general description of a 'typical' project is provided to enable you to put your responses in a context.

Your knowledge will be very helpful to us in our attempt to model contractual risks, and we would value the time spent in answering the questions in as much detail as you can. It would be particularly helpful if you could base your answers on your actual experience rather than rules of thumb or 'what might be generally expected'. If you find it helpful, please feel free to consult colleagues or other sources of expert opinion in formulating your answers. Obviously, if at any time you wish to change an answer you had given previously after giving it further thought, please feel free to do so.

The questionnaire is designed to be able to elicit your knowledge on the issues it raises, so any comments on the clarity and/or simplicity of the questions are most welcome. Please feel free to phone and ask for any further explanation that you may require regarding any question, and we will be delighted to provide all the explanations required.

When phoning, please contact:

Francis K. Adams
Tel.: 0131-334 4753
Fax: 0131-668 3053
e-mail: Francis.K.Adams@ed.ac.uk

Dr. Jake Ansell
Tel.: 0131-650 3806
Fax: 0131-668 3053
e-mail: J.Ansell@ed.ac.uk

When finished, please either return it in the pre-paid envelope provided or fax it to:

Francis K. Adams
Department of Business Studies
University of Edinburgh
William Robertson Building
50 George Square
Edinburgh
EH8 9JY
Fax: 0131 668 3053

Thank you for your cooperation and assistance with the study.

SECTION 1: PROFESSIONAL PROFILE

Please ignore this section if you participated in the survey on Risk Perception and simply either attach a business card or complete section 3.7 in addition to the remaining applicable sections of the questionnaire.

1.0 Approximately how long you have been involved in

(a) the construction industry? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

(b) your current profession? ❑ Under 10 years ❑ 10-20 years ❑ 20-30 years ❑ Over 30 years

2.0 Which one or two of the following best describe(s) the predominant nature of your professional experience?

❑ Building Contracting ❑ Civil Engineering Contracting

❑ Property Development ❑ Design Consulting

❑ Project Management Consulting ❑ Quantity Surveying/Cost Consulting

❑ Legal/Contracts Consulting ❑ Other (please specify): ....

3.0 Which one of the following best describes your present profession, job title or job function?

❑ Construction/Site Manager ❑ Project Manager

❑ Quantity Surveyor ❑ Contracts Manager

❑ Design Consultant ❑ Legal/Contracts Consultant

❑ Other (please specify): ....

4.0 (a) Do your job responsibilities include project risk assessment?

❑ Yes ❑ No

(b) If 'No', who in your company deals with project risk assessment?

(name/job title of individual): ....

5.0 (a) Have your various job responsibilities during the past 10 years included project risk assessments?

❑ Yes ❑ No

(b) If 'Yes', on what percentage of projects during the past 10 years have you had to prepare

i. Results of formal risk assessment? (approximately) .... %

ii. Measures to mitigate against risk effects? (approximately) .... %

iii. Acceptable Risk premiums for bidding purposes? (approximately) .... %

iv. Fall-back options to recover programme/cost (approximately) .... %

6.0 How many of the following types of contracts have you been involved with in the past 10 years?

(a) international (overseas) projects, generally ? (approximately) ....

(b) projects based in developed countries? (approximately) ....

(c) projects based in sub-Saharan Africa? (approximately) ....

(d) projects based in Ghana? (approximately) ....

7.0 What is the average Annual Turnover of your company (please tick (✓) as applicable)

❑ Under 5m ❑ £6m - 25m ❑ £26 - 50m ❑ Over 50m ❑ Unable to divulge

SECTION 2: RELATIVE LIKELIHOODS OF OCCURRENCE OF THE RISK OF PAYMENT DELAYS BY THE CLIENT IN INTERNATIONAL CONSTRUCTION CONTRACTS

The questions in this questionnaire assume the following project description as typical. Please make any other assumptions the way you normally would in estimating for risks in the absence of fully detailed information. Estimates are sought regarding the risk of payment delays by the client. Your responses should relate to levels of risk that are at least significant enough to merit your attention.

The contract is for a $5 million construction project based in an emerging enterprise zone in Ghana. The contract period (agreed project duration) is 2 years. The client is the Government of Ghana, but the project is being 85% financed by the World Bank while the Ghana Government is providing 15% funding in local currency. Payment for the works will be subsequent to the preparation and approval of monthly Interim Payment Certificates.

1.0 What estimate would you consider to be the <u>minimum</u> number of times that the risk, taken on its on, can materialise among a 100 of such projects?

....

2.0 What estimate would you consider to be the <u>maximum</u> number of times that the risk, taken on its own, can materialise among a 100 of such projects?

....

3.0 What estimate would you consider to be the <u>most likely</u> number of times that the risk, taken on its on, can materialise among a 100 of such projects ? (Let's call this number 'A')

....

4.0 If 'A' is the most likely number of times that the risk can occur and we assigned this number a proportional 'likelihood rating' of 60 units, what estimate <u>greater than</u> 'A' would you consider to be half as likely to materialise as 'A' (i.e. have a likelihood rating of 30 units)?

....

5.0 What estimate <u>smaller than</u> 'A' would you consider to be also half as likely to materialise as 'A' (i.e. have a likelihood rating of 30 units)?

....

6.0 What estimate <u>greater than</u> 'A' would you consider to be a quarter as likely to materialise as 'A' (i.e. have a likelihood rating of 15 units)?

....

7.0 What estimate <u>smaller than</u> 'A' would you consider to be also a quarter as likely to materialise as 'A' (i.e. have a likelihood rating of 15 units)?

....

Appendix 6 *(Continued)*

SECTION 3: SEVERITY OF THE RISK OF PAYMENT DELAYS BY THE CLIENT IN INTERNATIONAL CONSTRUCTION CONTRACTS

The questions in this section assume the following project description as typical. Make any other assumptions the way you normally would in estimating for risks in the absence of fully detailed information. Estimates are sought regarding the risk of payment delays by the client. Your responses should relate to levels of risk that are at least significant enough to merit your attention.

The contract is for a $5 million construction project based in an emerging enterprise zone in Ghana. The contract period (agreed project duration) is 2 years. The client is the Government of Ghana, but the project is being 85% financed by the World Bank while the Ghana Government is providing 15% funding in local currency. Payment for the works will be subsequent to the preparation and approval of monthly Interim Payment Certificates.

1.0 On a scale of 0-100 where 0 means 'No significant effect on project costs, duration or profits' and 100 means 'total loss of profits and/or a catastrophic escalation in project costs and/or duration', what would you estimate to be the minimum impact on the project cost should the risk materialise?

....

2.0 What estimate would you consider to be the maximum impact on the project cost should the risk materialise?

....

3.0 What estimate would you consider to be the most likely impact on the project cost should the risk materialise?

....

4.0 If 'A' is the estimate for the most likely impact of the risk on project cost and we assigned this level of impact proportional 'severity units' of 60, what estimate greater than 'A' will you consider to be half as likely to materialise as 'A' (i.e. have severity units of 30 units)?

....

5.0 What estimate smaller than 'A' will you consider to be half as likely to materialise as 'A' (i.e. have severity units of 30 units)?

....

6.0 What estimate greater than 'A' would you consider to be a quarter as likely to materialise as 'A' (i.e. have severity units of 15 units)?

....

7.0 What estimate smaller than 'A' would you consider to be also a quarter as likely to materialise as 'A' (i.e. have severity units of 15 units)?

....

For the rest of the questions in this questionnaire, please base your responses on your experiences in one of the following settings and indicate which region by ticking(4) one of the following:

❑ Ghana ❑ Sub-Saharan African countries ❑ Other developing countries

8.0 Please indicate the approximate number of times you have encountered a significant level of payment delays by the client (i.e. significant enough to merit your attention or affect the project) on the projects that have you been involved with in the past 10 years.

....

9.0 On a scale of 0-100 where 0 means 'No significant effect on project costs, duration or profits' and 100 means a catastrophic escalation in project costs, please indicate the impact of the risk on project cost for your most recent experience of payment delays by the client.

....

Appendix 6 *(Continued)*

SECTION 4: PERSONAL EXPERIENCES OF PAYMENT DELAYS

1.0 Approximately how many projects based in your selected geographical setting have you been involved with in the past 10 years?

....

2.0 Approximately how many of these projects had the following as the primary source of funding?

	Funding Source	No. of Projects
i.	Local-Government	....
ii.	Local-Private (Company/Individual)	....
iii.	External (e.g. World Bank/IMF/Donor Country)	....
iv.	Other Source (specify):	....

3.0 Please indicate on approximately how many of the projects with the following primary source of client-funding you encountered payment delays, and the average impact of the delays (on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'a catastrophic escalation in project costs'):

	Funding Source	No. of Projects	Average Impact
i.	Local-Government	....	....
ii.	Local-Private (Company/Individual)	....	....
iii.	External (e.g. World Bank/IMF/Donor Country)	....	....
iv.	Other Source (specify):	....	....

4.0 For your most recent experience of payment delays, please indicate on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'a catastrophic escalation in project costs', the initial estimates made, if any, for the impact of the risk on project cost:

....

5.0 Please indicate, on a scale of 0-100, where 0 means 'No significant effect' and 100 means 'a catastrophic escalation in project costs', the approximate realised impact of the risk on project cost for your most recent experience of payment delays:

....

6.0 Please indicate the client's primary source of funding for the two most recent occurrences of payment delays in your selected setting (please tick (4) only one per project)

Funding Source	Project 1	Project 2	Funding Source	Project 1	Project 2
i. Local-Government	❑	❑	ii. Local-Private Client	❑	❑
iii. External (e.g. World Bank)	❑	❑	iv. Other Source:	❑	❑

6.0 What estimate greater than 'A' would you consider to be a quarter as likely to materialise as 'A' (i.e. have severity units of 15 units)?

....

7.0 Would you be willing to provide feedback on this questionnaire when contacted? ❑ Yes ❑ No

If 'Yes', please either complete your details below or attach your business card so we may be able to contact you.

Title: .... First Name(s): .... Surname: ....

Job Title: ....

Company: ....

Contact Address: ....

Contact Telephone: .... Fax: ....

Thank you very much for your contribution. Please either return it in the pre-paid envelope provided or fax it to: F. K. Adams • Department of Business Studies • Fax: 0131 668 3053

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APPENDIX 7

CALCULATION OF RISK LIKELIHOOD RATINGS AND PROBABILITIES

Occurrences	Risk Likelihood Rating: Ghana Rating: Plotted	Ghana Rating: Smoothed (L_g)	Ghana Rating: Probabilities ($L_g / \sum L_g$)	UK Rating: Plotted	UK Rating: Smoothed (L_u)	UK Rating: Probabilities ($L_u / \sum L_u$)
0	-	1.0	0.000	-	0.8	0.000
1	-	1.3	0.001	-	1.0	0.001
2	-	1.5	0.001	-	1.2	0.001
3	-	1.8	0.001	-	1.7	0.001
4	-	2.0	0.001	-	2.0	0.001
5	-	2.1	0.001	-	2.1	0.001
6	-	2.3	0.001	-	2.5	0.001
7	-	2.6	0.001	-	2.8	0.001
8	-	3.0	0.001	-	3.0	0.002
9	-	3.1	0.001	-	3.2	0.002
10	-	3.3	0.002	-	3.6	0.002
11	-	3.6	0.002	-	3.8	0.002
12	-	3.8	0.002	-	4.0	0.002
13	-	4.0	0.002	-	4.4	0.002
14	-	4.1	0.002	-	4.8	0.003
15	-	4.5	0.002	-	5.0	0.003
16	-	4.8	0.002	-	5.2	0.003
17	-	5.0	0.002	-	5.5	0.003
18	-	5.2	0.002	-	5.8	0.003
19	-	5.7	0.003	-	6.0	0.003
20	-	6.0	0.003	-	6.5	0.003
21	-	6.3	0.003	-	6.8	0.004
22	-	6.6	0.003	-	7.0	0.004
23	-	6.8	0.003	-	7.4	0.004
24	-	7.1	0.003	-	7.8	0.004
25	-	7.6	0.003	-	8.0	0.004
26	-	8.0	0.004	-	8.2	0.004
27	-	8.5	0.004	-	8.5	0.004
28	-	9.0	0.004	-	9.0	0.005
29	-	9.5	0.004	-	9.3	0.005
30	-	10.1	0.005	-	9.9	0.005
31	-	11.0	0.005	-	10.5	0.006
32	-	11.5	0.005	-	11.2	0.006
33	-	12.1	0.006	-	12.5	0.007
34	-	13.0	0.006	15	14.8	0.008
35	-	14.0	0.006	-	16.0	0.008
36	15	15.0	0.007	-	18.5	0.010
37	-	16.0	0.007	-	21.5	0.011
38	-	17.2	0.008	-	24.5	0.013
39	-	19.0	0.009	-	27.5	0.014
40	-	20.2	0.009	30	30.0	0.016

Appendix 7 *(Continued)*

Risk Likelihood Rating						
	Ghana Rating			UK Rating		
Occurrences	Plotted	Smoothed (L_g)	Probabilities ($L_g / \sum L_g$)	Plotted	Smoothed (L_u)	Probabilities ($L_u / \sum L_u$)
41	-	22.0	0.010	-	32.2	0.017
42	-	23.0	0.011	-	35.3	0.019
43	-	25.0	0.011	-	39.0	0.020
44	-	26.0	0.012	-	42.0	0.022
45	-	27.0	0.012	-	45.0	0.024
46	-	28.8	0.013	-	48.0	0.025
47	30	30.0	0.014	-	51.0	0.027
48	-	31.0	0.014	-	53.2	0.028
49	-	32.8	0.015	-	55.2	0.029
50	-	34.0	0.016	-	57.2	0.030
51	-	35.0	0.016	-	59.0	0.031
52	-	36.8	0.017	-	59.8	0.031
53	-	38.0	0.017	60	60.0	0.031
54	-	39.2	0.018	-	59.2	0.031
55	-	41.0	0.019	-	58.3	0.031
56	-	42.0	0.019	-	57.0	0.030
57	-	43.0	0.020	-	55.0	0.029
58	-	44.8	0.020	-	52.8	0.028
59	-	46.0	0.021	-	50.0	0.026
60	-	47.2	0.022	-	47.2	0.025
61	-	49.0	0.022	-	45.0	0.024
62	-	50.0	0.023	-	41.5	0.022
63	-	51.0	0.023	-	38.7	0.020
64	-	52.3	0.024	-	35.8	0.019
65	-	53.2	0.024	-	33.0	0.017
66	-	55.0	0.025	30	30.0	0.016
67	-	55.8	0.026	-	28.5	0.015
68	-	56.9	0.026	-	26.0	0.014
69	-	57.8	0.026	-	24.5	0.013
70	-	58.9	0.027	-	22.8	0.012
71	-	59.3	0.027	-	20.8	0.011
72	-	59.8	0.027	-	18.8	0.010
73	60	60.0	0.027	-	17.0	0.009
74	-	59.7	0.027	15	15.0	0.008
75	-	58.5	0.027	-	14.0	0.007
76	-	56.0	0.026	-	12.0	0.006
77	-	51.0	0.023	-	11.0	0.006
78	-	39.0	0.018	-	10.0	0.005
79	30	30.0	0.014	-	9.0	0.005
80	-	26.8	0.012	-	8.5	0.004

Appendix 7 *(Continued)*

Risk Likelihood Rating						
Occurrences	Ghana Rating			UK Rating		
	Plotted	Smoothed (L_g)	Probabilities ($L_g / \sum L_g$)	Plotted	Smoothed (L_u)	Probabilities ($L_u / \sum L_u$)
81	-	23.0	0.011	-	8.0	0.004
82	-	20.0	0.009	-	7.5	0.004
83	-	17.0	0.008	-	7.0	0.004
84	15	14.8	0.007	-	6.8	0.004
85	-	12.0	0.005	-	6.2	0.003
86	-	10.0	0.005	-	5.8	0.003
87	-	9.0	0.004	-	5.2	0.003
88	-	8.0	0.004	-	4.8	0.003
89	-	6.9	0.003	-	4.5	0.002
90	-	6.0	0.003	-	4.0	0.002
91	-	5.0	0.002	-	3.7	0.002
92	-	4.5	0.002	-	3.2	0.002
93	-	4.0	0.002	-	3.0	0.002
94	-	3.3	0.002	-	2.8	0.001
95	-	3.0	0.001	-	2.5	0.001
96	-	2.4	0.001	-	2.5	0.001
97	-	2.0	0.001	-	2.0	0.001
98	-	1.5	0.001	-	1.8	0.001
99	-	1.0	0.000	-	1.5	0.001
100	-	0.5	0.000	-	1.0	0.001
Totals		**2185.7**	**1.000**		**1905.9**	**1.000**

APPENDIX 8

CALCULATION OF RISK IMPACT RATINGS AND PROBABILITIES (MAIN SURVEY)

Impact Scale	Risk Impact Rating					
	Ghana Rating			UK Rating		
	Plotted	Smoothed (L_g)	Probabilities ($L_g / \sum L_g$)	Plotted	Smoothed (L_u)	Probabilities ($L_u / \sum L_u$)
0	-	7.6	0.005	-	0.9	0.000
1	-	8.0	0.005	-	1.2	0.001
2	-	8.2	0.005	-	1.8	0.001
3	-	8.5	0.005	-	2.1	0.001
4	-	8.7	0.005	-	2.5	0.001
5	-	9.0	0.006	-	3.0	0.002
6	-	9.2	0.006	-	3.3	0.002
7	-	9.4	0.006	-	3.6	0.002
8	-	9.6	0.006	-	4.0	0.002
9	-	9.8	0.006	-	4.5	0.002
10	-	10.0	0.006	-	5.0	0.003
11	-	10.3	0.006	-	5.2	0.003
12	-	10.5	0.006	-	5.8	0.003
13	-	10.8	0.007	-	6.1	0.003
14	-	11.0	0.007	-	6.6	0.003
15	-	11.3	0.007	-	7.1	0.004
16	-	11.8	0.007	-	7.7	0.004
17	-	12.0	0.007	-	8.2	0.004
18	-	12.3	0.008	-	9.0	0.005
19	-	12.8	0.008	-	9.5	0.005
20	-	13.1	0.008	-	10.4	0.005
21	-	13.8	0.008	-	11.5	0.006
22	-	14.4	0.009	-	12.8	0.007
23	15	15.0	0.009	15	14.5	0.007
24	-	15.6	0.010	-	16.1	0.008
25	-	16.3	0.010	-	18.2	0.009
26	-	17.0	0.010	-	20.9	0.011
27	-	17.5	0.011	-	23.5	0.012
28	-	18.0	0.011	-	26.5	0.014
29	-	18.8	0.011	30	29.2	0.015
30	-	19.4	0.012	-	32.5	0.017
31	-	20.0	0.012	-	37.0	0.019
32	-	20.8	0.013	-	41.5	0.021
33	-	21.5	0.013	-	46.5	0.024
34	-	22.0	0.013	-	50.5	0.026
35	-	22.9	0.014	-	54.3	0.028
36	-	23.8	0.015	-	57.1	0.029
37	-	24.5	0.015	-	59.0	0.030
38	-	25.5	0.016	60	60.0	0.031
39	-	26.6	0.016	-	58.8	0.030
40	-	27.6	0.017	-	57.7	0.030

Appendix 8 *(Continued)*

Impact Scale	Risk Impact Rating: Ghana Rating			UK Rating		
	Plotted	Smoothed (L_g)	Probabilities ($L_g / \sum L_g$)	Plotted	Smoothed (L_u)	Probabilities ($L_u / \sum L_u$)
41	-	29.0	0.018	-	57.2	0.029
42	30	30.2	0.018	-	55.2	0.028
43	-	32.5	0.020	-	53.0	0.027
44	-	34.8	0.021	-	50.5	0.026
45	-	37.5	0.023	-	47.0	0.024
46	-	41.0	0.025	-	45.3	0.023
47	-	44.5	0.027	-	42.5	0.022
48	-	48.0	0.029	-	39.5	0.020
49	-	52.0	0.032	-	37.0	0.019
50	-	55.8	0.034	-	34.2	0.018
51	-	59.0	0.036	-	31.6	0.016
52	60	60.0	0.037	30	29.5	0.015
53	-	58.8	0.036	-	27.5	0.014
54	-	46.0	0.028	-	25.5	0.013
55	30	32.0	0.020	-	24.0	0.012
56	-	28.0	0.017	-	23.0	0.012
57	-	25.0	0.015	-	22.1	0.011
58	-	23.0	0.014	15	21.5	0.011
59	-	21.0	0.013	-	20.8	0.011
60	-	19.5	0.012	-	20.1	0.010
61	-	18.0	0.011	-	19.5	0.010
62	-	16.6	0.010	-	19.0	0.010
63	15	15.3	0.009	-	18.2	0.009
64	-	14.0	0.009	-	17.8	0.009
65	-	12.7	0.008	-	17.2	0.009
66	-	11.5	0.007	-	16.5	0.008
67	-	10.5	0.006	-	16.0	0.008
68	-	9.5	0.006	-	15.5	0.008
69	-	9.0	0.006	-	15.0	0.008
70	-	8.5	0.005	-	14.5	0.007
71	-	8.0	0.005	-	14.0	0.007
72	-	7.5	0.005	-	13.5	0.007
73	0	7.0	0.004	-	13.0	0.007
74	-	6.7	0.004	-	12.5	0.006
75	-	6.4	0.004	-	12.0	0.006
76	-	6.1	0.004	-	11.4	0.006
77	-	5.8	0.004	-	11.0	0.006
78	-	5.5	0.003	-	10.5	0.005
79	-	5.2	0.003	-	10.0	0.005
80	-	5.0	0.003	-	9.5	0.005

Appendix 8 *(Continued)*

Impact Scale	Risk Impact Rating					
	Ghana Rating			UK Rating		
	Plotted	Smoothed (L_g)	Probabilities ($L_g / \sum L_g$)	Plotted	Smoothed (L_u)	Probabilities ($L_u / \sum L_u$)
81	-	4.8	0.003	-	9.0	0.005
82	-	4.6	0.003	-	8.5	0.004
83	-	4.4	0.003	0	8.1	0.004
84	-	4.0	0.002	-	7.6	0.004
85	-	3.8	0.002	-	7.3	0.004
86	-	3.6	0.002	-	7.0	0.004
87	-	3.4	0.002	-	6.5	0.003
88	-	3.2	0.002	-	6.2	0.003
89	-	3.0	0.002	-	6.0	0.003
90	-	2.8	0.002	-	5.5	0.003
91	-	2.6	0.002	-	5.3	0.003
92	-	2.4	0.001	-	5.1	0.003
93	-	2.2	0.001	-	4.9	0.003
94	-	1.9	0.001	-	4.6	0.002
95	-	1.7	0.001	-	4.4	0.002
96	-	1.5	0.001	-	4.2	0.002
97	-	1.4	0.001	-	4.0	0.002
98	-	1.0	0.001	-	3.7	0.002
99	-	0.8	0.000	-	3.5	0.002
100	-	0.5	0.000	-	3.1	0.002
Totals		**1634.9**	**1.000**		**1943.7**	**1.000**

APPENDIX 9

SCALED ESTIMATES AND ASSESSED PROBABILITIES FOR THE OCCURRENCE OF ADVERSE GROUND CONDITIONS (RELATIVE LIKELIHOOD METHOD)

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000	0.000
1	1.5	2.0	0.5	0.5	1.0	0.001	0.002	0.000	0.000	0.001
2	3.5	4.6	1.3	1.0	1.8	0.002	0.004	0.001	0.001	0.002
3	5.5	7.0	2.0	1.5	2.5	0.004	0.007	0.002	0.001	0.002
4	8.0	9.5	3.0	2.3	3.0	0.006	0.009	0.003	0.002	0.003
5	10.0	12.4	4.0	2.8	4.0	0.007	0.012	0.004	0.003	0.003
6	12.9	16.0	4.8	3.3	5.0	0.009	0.016	0.005	0.003	0.004
7	16.0	21.0	5.3	4.0	5.5	0.011	0.020	0.005	0.004	0.005
8	20.3	26.0	6.2	4.5	6.4	0.014	0.025	0.006	0.004	0.005
9	24.0	31.5	7.0	5.0	7.4	0.017	0.031	0.007	0.005	0.006
10	28.0	38.0	7.8	5.4	8.0	0.020	0.037	0.008	0.005	0.007
11	32.0	45.0	8.8	6.0	9.0	0.023	0.044	0.009	0.006	0.008
12	38.0	52.0	9.6	6.6	10.5	0.027	0.051	0.009	0.006	0.009
13	44.5	57.0	10.5	7.2	12.0	0.032	0.056	0.010	0.007	0.010
14	50.0	60.0	11.5	8.0	16.0	0.035	0.058	0.011	0.008	0.014
15	55.0	55.0	16.6	8.4	20.0	0.039	0.054	0.016	0.008	0.017
16	58.0	41.0	15.5	9.0	25.0	0.041	0.040	0.015	0.009	0.021
17	59.0	30.0	17.0	9.8	30.0	0.042	0.029	0.017	0.010	0.025
18	59.0	25.0	20.0	10.3	35.8	0.042	0.024	0.019	0.010	0.030
19	58.5	21.0	25.0	11.0	42.0	0.041	0.020	0.024	0.011	0.036
20	56.5	18.0	30.0	12.0	48.8	0.040	0.018	0.029	0.012	0.041
21	53.2	16.0	36.0	13.0	54.5	0.038	0.016	0.035	0.013	0.046
22	50.5	14.2	43.0	15.0	58.5	0.036	0.014	0.042	0.015	0.050
23	46.8	13.1	50.0	18.0	60.0	0.033	0.013	0.049	0.018	0.051
24	43.0	12.1	55.0	24.0	59.0	0.030	0.012	0.054	0.023	0.050
25	39.0	11.5	59.0	30.0	55.5	0.028	0.011	0.057	0.029	0.047
26	35.2	11.0	60.0	37.0	49.5	0.025	0.011	0.058	0.036	0.042
27	32.0	10.6	59.0	45.0	43.5	0.023	0.010	0.057	0.044	0.037
28	29.0	10.2	56.5	52.0	38.0	0.021	0.010	0.055	0.051	0.032
29	25.2	10.0	53.0	57.5	32.2	0.018	0.010	0.052	0.056	0.027
30	21.2	9.9	49.2	60.0	27.5	0.015	0.010	0.048	0.058	0.023
31	18.0	9.8	45.2	57.3	23.5	0.013	0.010	0.044	0.056	0.020
32	15.2	9.6	40.9	50.0	19.5	0.011	0.009	0.040	0.049	0.017
33	13.3	9.4	36.6	42.0	16.5	0.009	0.009	0.036	0.041	0.014
34	12.0	9.2	32.5	35.0	13.6	0.008	0.009	0.032	0.034	0.012

Appendix 9 *(Continued)*

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
35	11.2	9.0	29.5	30.0	11.8	0.008	0.009	0.029	0.029	0.010
36	10.8	8.9	26.5	26.6	11.0	0.008	0.009	0.026	0.026	0.009
37	10.2	8.8	23.2	24.2	10.2	0.007	0.009	0.023	0.024	0.009
38	10.0	8.6	20.4	22.1	10.0	0.007	0.008	0.020	0.022	0.008
39	9.8	8.4	18.2	20.1	9.8	0.007	0.008	0.018	0.020	0.008
40	9.5	8.2	16.5	18.6	9.5	0.007	0.008	0.016	0.018	0.008
41	9.3	8.0	15.2	17.3	9.3	0.007	0.008	0.015	0.017	0.008
42	9.1	7.9	14.2	16.1	9.1	0.006	0.008	0.014	0.016	0.008
43	9.0	7.7	13.5	15.2	9.0	0.006	0.008	0.013	0.015	0.008
44	8.9	7.6	13.0	14.5	8.9	0.006	0.007	0.013	0.014	0.008
45	8.7	7.4	12.6	14.0	8.7	0.006	0.007	0.012	0.014	0.007
46	8.5	7.3	12.2	13.2	8.5	0.006	0.007	0.012	0.013	0.007
47	8.2	7.2	11.8	13.0	8.2	0.006	0.007	0.011	0.013	0.007
48	8.0	7.0	11.5	12.6	8.0	0.006	0.007	0.011	0.012	0.007
49	7.9	6.9	11.2	12.4	7.9	0.006	0.007	0.011	0.012	0.007
50	7.8	6.8	10.9	12.1	7.8	0.006	0.007	0.011	0.012	0.007
51	7.6	6.6	10.7	11.9	7.6	0.005	0.006	0.010	0.012	0.006
52	7.4	6.5	10.3	11.6	7.4	0.005	0.006	0.010	0.011	0.006
53	7.2	6.4	10.1	11.4	7.2	0.005	0.006	0.010	0.011	0.006
54	7.0	6.2	9.9	11.1	7.0	0.005	0.006	0.010	0.011	0.006
55	6.8	6.1	9.7	10.9	6.8	0.005	0.006	0.009	0.011	0.006
56	6.7	6.0	9.5	10.7	6.7	0.005	0.006	0.009	0.010	0.006
57	6.5	5.8	9.3	10.4	6.5	0.005	0.006	0.009	0.010	0.006
58	6.4	5.7	9.1	10.2	6.4	0.004	0.006	0.009	0.010	0.005
59	6.2	5.6	8.8	9.9	6.2	0.004	0.005	0.009	0.010	0.005
60	6.1	5.4	8.6	9.7	6.1	0.004	0.005	0.008	0.009	0.005
61	5.9	5.3	8.4	9.5	5.9	0.004	0.005	0.008	0.009	0.005
62	5.8	5.2	8.2	9.2	5.8	0.004	0.005	0.008	0.009	0.005
63	5.6	5.0	8.0	9.0	5.6	0.004	0.005	0.008	0.009	0.005
64	5.5	4.9	7.8	8.7	5.5	0.004	0.005	0.008	0.009	0.005
65	5.3	4.7	7.6	8.5	5.3	0.004	0.005	0.007	0.008	0.004
66	5.2	4.6	7.3	8.2	5.2	0.004	0.004	0.007	0.008	0.004
67	5.0	4.5	7.1	8.0	5.0	0.004	0.004	0.007	0.008	0.004
68	4.9	4.3	6.9	7.8	4.9	0.003	0.004	0.007	0.008	0.004
69	4.7	4.2	6.7	7.5	4.7	0.003	0.004	0.007	0.007	0.004
70	4.6	4.1	6.5	7.3	4.6	0.003	0.004	0.006	0.007	0.004

Appendix 9 (*Continued*)

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
41	9.3	8.0	15.2	17.3	9.3	0.007	0.008	0.015	0.017	0.008
42	9.1	7.9	14.2	16.1	9.1	0.006	0.008	0.014	0.016	0.008
43	9.0	7.7	13.5	15.2	9.0	0.006	0.008	0.013	0.015	0.008
44	8.9	7.6	13.0	14.5	8.9	0.006	0.007	0.013	0.014	0.008
45	8.7	7.4	12.6	14.0	8.7	0.006	0.007	0.012	0.014	0.007
46	8.5	7.3	12.2	13.2	8.5	0.006	0.007	0.012	0.013	0.007
47	8.2	7.2	11.8	13.0	8.2	0.006	0.007	0.011	0.013	0.007
48	8.0	7.0	11.5	12.6	8.0	0.006	0.007	0.011	0.012	0.007
49	7.9	6.9	11.2	12.4	7.9	0.006	0.007	0.011	0.012	0.007
50	7.8	6.8	10.9	12.1	7.8	0.006	0.007	0.011	0.012	0.007
51	7.6	6.6	10.7	11.9	7.6	0.005	0.006	0.010	0.012	0.006
52	7.4	6.5	10.3	11.6	7.4	0.005	0.006	0.010	0.011	0.006
53	7.2	6.4	10.1	11.4	7.2	0.005	0.006	0.010	0.011	0.006
54	7.0	6.2	9.9	11.1	7.0	0.005	0.006	0.010	0.011	0.006
55	6.8	6.1	9.7	10.9	6.8	0.005	0.006	0.009	0.011	0.006
56	6.7	6.0	9.5	10.7	6.7	0.005	0.006	0.009	0.010	0.006
57	6.5	5.8	9.3	10.4	6.5	0.005	0.006	0.009	0.010	0.006
58	6.4	5.7	9.1	10.2	6.4	0.004	0.006	0.009	0.010	0.005
59	6.2	5.6	8.8	9.9	6.2	0.004	0.005	0.009	0.010	0.005
60	6.1	5.4	8.6	9.7	6.1	0.004	0.005	0.008	0.009	0.005
61	5.9	5.3	8.4	9.5	5.9	0.004	0.005	0.008	0.009	0.005
62	5.8	5.2	8.2	9.2	5.8	0.004	0.005	0.008	0.009	0.005
63	5.6	5.0	8.0	9.0	5.6	0.004	0.005	0.008	0.009	0.005
64	5.5	4.9	7.8	8.7	5.5	0.004	0.005	0.008	0.009	0.005
65	5.3	4.7	7.6	8.5	5.3	0.004	0.005	0.007	0.008	0.004
66	5.2	4.6	7.3	8.2	5.2	0.004	0.004	0.007	0.008	0.004
67	5.0	4.5	7.1	8.0	5.0	0.004	0.004	0.007	0.008	0.004
68	4.9	4.3	6.9	7.8	4.9	0.003	0.004	0.007	0.008	0.004
69	4.7	4.2	6.7	7.5	4.7	0.003	0.004	0.007	0.007	0.004
70	4.6	4.1	6.5	7.3	4.6	0.003	0.004	0.006	0.007	0.004
71	4.4	3.9	6.3	7.0	4.4	0.003	0.004	0.006	0.007	0.004
72	4.2	3.8	6.0	6.8	4.2	0.003	0.004	0.006	0.007	0.004
73	4.1	3.7	5.8	6.6	4.1	0.003	0.004	0.006	0.006	0.003
74	3.9	3.5	5.6	6.3	3.9	0.003	0.003	0.005	0.006	0.003
75	3.8	3.4	5.4	6.1	3.8	0.003	0.003	0.005	0.006	0.003
76	3.6	3.3	5.2	5.8	3.6	0.003	0.003	0.005	0.006	0.003
77	3.5	3.1	5.0	5.6	3.5	0.002	0.003	0.005	0.005	0.003
78	3.3	3.0	4.8	5.3	3.3	0.002	0.003	0.005	0.005	0.003
80	3.0	2.7	4.3	4.9	3.0	0.002	0.003	0.004	0.005	0.003

Appendix 9 (*Continued*)

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
71	4.4	3.9	6.3	7.0	4.4	0.003	0.004	0.006	0.007	0.004
72	4.2	3.8	6.0	6.8	4.2	0.003	0.004	0.006	0.007	0.004
73	4.1	3.7	5.8	6.6	4.1	0.003	0.004	0.006	0.006	0.003
74	3.9	3.5	5.6	6.3	3.9	0.003	0.003	0.005	0.006	0.003
75	3.8	3.4	5.4	6.1	3.8	0.003	0.003	0.005	0.006	0.003
76	3.6	3.3	5.2	5.8	3.6	0.003	0.003	0.005	0.006	0.003
77	3.5	3.1	5.0	5.6	3.5	0.002	0.003	0.005	0.005	0.003
78	3.3	3.0	4.8	5.3	3.3	0.002	0.003	0.005	0.005	0.003
80	3.0	2.7	4.3	4.9	3.0	0.002	0.003	0.004	0.005	0.003
81	2.9	2.6	4.1	4.6	2.9	0.002	0.003	0.004	0.004	0.002
81	2.9	2.6	4.1	4.6	2.9	0.002	0.003	0.004	0.004	0.002
82	2.7	2.5	3.9	4.4	2.7	0.002	0.002	0.004	0.004	0.002
83	2.6	2.3	3.7	4.1	2.6	0.002	0.002	0.004	0.004	0.002
84	2.4	2.2	3.5	3.9	2.4	0.002	0.002	0.003	0.004	0.002
85	2.3	2.0	3.3	3.6	2.3	0.002	0.002	0.003	0.004	0.002
86	2.1	1.9	3.0	3.4	2.1	0.002	0.002	0.003	0.003	0.002
87	2.0	1.8	2.8	3.2	2.0	0.001	0.002	0.003	0.003	0.002
88	1.8	1.6	2.6	2.9	1.8	0.001	0.002	0.003	0.003	0.002
89	1.7	1.5	2.4	2.7	1.7	0.001	0.001	0.002	0.003	0.001
90	1.5	1.4	2.2	2.4	1.5	0.001	0.001	0.002	0.002	0.001
91	1.4	1.2	2.0	2.2	1.4	0.001	0.001	0.002	0.002	0.001
92	1.2	1.1	1.7	2.0	1.2	0.001	0.001	0.002	0.002	0.001
93	1.1	1.0	1.5	1.7	1.1	0.001	0.001	0.001	0.002	0.001
94	0.9	0.8	1.3	1.5	0.9	0.001	0.001	0.001	0.001	0.001
95	0.8	0.7	1.1	1.2	0.8	0.001	0.001	0.001	0.001	0.001
96	0.6	0.6	0.9	1.0	0.6	0.000	0.001	0.001	0.001	0.001
97	0.5	0.4	0.7	0.7	0.5	0.000	0.000	0.001	0.001	0.000
98	0.3	0.3	0.5	0.5	0.3	0.000	0.000	0.000	0.000	0.000
99	0.2	0.2	0.2	0.3	0.2	0.000	0.000	0.000	0.000	0.000
100	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000	0.000
Total	**1,412.0**	**1,026.7**	**1,026.7**	**1,026.7**	**1,179.5**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

APPENDIX 10

SCALED ESTIMATES AND ASSESSED PROBABILITIES FOR THE OCCURRENCE OF ADVERSE GROUND CONDITIONS (CONTINUOUS VARIABLE SCALING METHOD)

	Relative Likelihood (Smoothed)					Assessed Probability				
Number of Occurrences of Adverse Ground Conditions	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
0	13	3	15	1	13	0.006	0.001	0.005	0.000	0.005
1	16	20	22	18	21	0.007	0.007	0.007	0.007	0.008
2	19	37	29	36	30	0.008	0.012	0.009	0.014	0.012
3	22	54	36	53	39	0.009	0.018	0.012	0.021	0.016
4	25	71	43	71	48	0.011	0.024	0.014	0.028	0.019
5	28	88	50	88	57	0.012	0.029	0.016	0.035	0.023
6	29	86	49	85	56	0.012	0.029	0.016	0.034	0.022
7	30	84	49	83	56	0.013	0.028	0.016	0.033	0.022
8	32	82	48	80	55	0.014	0.027	0.016	0.032	0.022
9	33	80	48	77	54	0.014	0.027	0.015	0.031	0.022
10	35	78	47	75	54	0.015	0.026	0.015	0.030	0.021
11	36	76	47	72	53	0.016	0.025	0.015	0.028	0.021
12	38	74	46	69	52	0.016	0.025	0.015	0.027	0.021
13	40	72	46	67	51	0.017	0.024	0.015	0.026	0.020
14	41	70	45	64	51	0.018	0.023	0.015	0.025	0.020
15	42	68	45	62	50	0.018	0.022	0.014	0.024	0.020
16	44	65	44	59	49	0.019	0.022	0.014	0.023	0.020
17	45	63	44	56	49	0.019	0.021	0.014	0.022	0.019
18	47	61	43	54	48	0.020	0.020	0.014	0.021	0.019
19	48	59	43	51	47	0.021	0.020	0.014	0.020	0.019
20	50	57	42	48	47	0.022	0.019	0.014	0.019	0.018
21	51	55	42	46	46	0.022	0.018	0.014	0.018	0.018
22	53	53	41	43	45	0.023	0.018	0.013	0.017	0.018
23	54	51	41	40	44	0.023	0.017	0.013	0.016	0.018
24	56	49	40	38	44	0.024	0.016	0.013	0.015	0.017
25	57	47	40	35	43	0.025	0.016	0.013	0.014	0.017
26	55	46	39	34	42	0.024	0.015	0.013	0.014	0.017
27	54	45	39	34	41	0.023	0.015	0.013	0.013	0.016
28	52	44	39	33	40	0.023	0.015	0.013	0.013	0.016
29	51	43	38	32	39	0.022	0.014	0.012	0.013	0.016
30	49	43	38	32	39	0.021	0.014	0.012	0.013	0.015
31	48	42	38	31	38	0.021	0.014	0.012	0.012	0.015
32	46	41	37	31	37	0.020	0.014	0.012	0.012	0.015

Appendix 10 (*Continued*)

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
33	45	40	37	30	36	0.019	0.013	0.012	0.012	0.014
34	43	39	37	29	35	0.019	0.013	0.012	0.012	0.014
35	42	38	37	29	34	0.018	0.013	0.012	0.011	0.013
36	40	37	36	28	33	0.017	0.012	0.012	0.011	0.013
37	39	36	36	27	32	0.017	0.012	0.012	0.011	0.013
38	37	35	36	27	31	0.016	0.012	0.012	0.011	0.012
39	36	34	35	26	30	0.015	0.011	0.012	0.010	0.012
40	34	34	35	25	30	0.015	0.011	0.011	0.010	0.012
41	33	33	35	25	29	0.014	0.011	0.011	0.010	0.011
42	31	32	34	24	28	0.013	0.011	0.011	0.010	0.011
43	30	31	34	23	27	0.013	0.010	0.011	0.009	0.011
44	28	30	34	23	26	0.012	0.010	0.011	0.009	0.010
45	27	29	34	22	25	0.011	0.010	0.011	0.009	0.010
46	25	28	33	22	24	0.011	0.009	0.011	0.009	0.010
47	24	27	33	21	23	0.010	0.009	0.011	0.008	0.009
48	22	26	33	20	22	0.009	0.009	0.011	0.008	0.009
49	21	25	32	20	21	0.009	0.008	0.011	0.008	0.008
50	19	25	32	19	21	0.008	0.008	0.010	0.008	0.008
51	18	24	31	18	20	0.008	0.008	0.010	0.007	0.008
52	18	23	31	18	20	0.008	0.008	0.010	0.007	0.008
53	17	23	30	17	19	0.008	0.008	0.010	0.007	0.008
54	17	22	30	17	19	0.007	0.007	0.010	0.007	0.007
55	16	21	29	16	18	0.007	0.007	0.010	0.006	0.007
56	16	21	29	16	18	0.007	0.007	0.009	0.006	0.007
57	15	20	28	15	17	0.007	0.007	0.009	0.006	0.007
58	15	19	28	15	17	0.006	0.006	0.009	0.006	0.007
59	14	19	27	14	16	0.006	0.006	0.009	0.006	0.006
60	14	18	26	14	16	0.006	0.006	0.009	0.005	0.006
61	13	17	26	13	15	0.006	0.006	0.008	0.005	0.006
62	13	17	25	13	15	0.005	0.006	0.008	0.005	0.006
63	12	16	25	12	15	0.005	0.005	0.008	0.005	0.006
64	12	15	24	12	14	0.005	0.005	0.008	0.005	0.006
65	11	15	24	11	14	0.005	0.005	0.008	0.004	0.005
66	11	14	23	11	13	0.005	0.005	0.008	0.004	0.005
67	10	13	22	10	13	0.004	0.004	0.007	0.004	0.005
68	10	13	22	10	12	0.004	0.004	0.007	0.004	0.005
69	9	12	21	9	12	0.004	0.004	0.007	0.004	0.005

Appendix 10 (*Continued)*

Number of Occurrences of Adverse Ground Conditions	Relative Likelihood (Smoothed)					Assessed Probability				
	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate	Construction Managers	Project Managers	Quantity Surveyors	Contracts Managers	Group Aggregate
70	9	11	21	9	11	0.004	0.004	0.007	0.003	0.004
71	8	11	20	8	11	0.003	0.004	0.007	0.003	0.004
72	8	10	20	8	10	0.003	0.003	0.006	0.003	0.004
73	7	9	19	7	10	0.003	0.003	0.006	0.003	0.004
74	7	9	19	7	9	0.003	0.003	0.006	0.003	0.004
75	6	8	18	6	9	0.003	0.003	0.006	0.002	0.004
76	6	8	18	6	9	0.003	0.003	0.006	0.002	0.004
77	6	8	18	6	9	0.002	0.003	0.006	0.002	0.003
78	6	7	18	5	9	0.002	0.002	0.006	0.002	0.003
79	6	7	19	5	8	0.002	0.002	0.006	0.002	0.003
80	5	7	19	5	8	0.002	0.002	0.006	0.002	0.003
81	5	7	19	5	8	0.002	0.002	0.006	0.002	0.003
82	5	6	19	5	8	0.002	0.002	0.006	0.002	0.003
83	5	6	19	4	8	0.002	0.002	0.006	0.002	0.003
84	5	6	19	4	8	0.002	0.002	0.006	0.002	0.003
85	5	6	19	4	8	0.002	0.002	0.006	0.002	0.003
86	5	6	19	4	7	0.002	0.002	0.006	0.002	0.003
87	5	5	20	4	7	0.002	0.002	0.006	0.001	0.003
88	4	5	20	3	7	0.002	0.002	0.006	0.001	0.003
89	4	5	20	3	7	0.002	0.002	0.006	0.001	0.003
90	4	5	20	3	7	0.002	0.002	0.006	0.001	0.003
91	4	4	20	3	7	0.002	0.001	0.007	0.001	0.003
92	4	4	20	3	6	0.002	0.001	0.007	0.001	0.003
93	4	4	20	2	6	0.002	0.001	0.007	0.001	0.003
94	4	4	20	2	6	0.002	0.001	0.007	0.001	0.002
95	4	4	21	2	6	0.002	0.001	0.007	0.001	0.002
96	3	3	20	2	6	0.001	0.001	0.007	0.001	0.002
97	2	2	20	2	5	0.001	0.001	0.006	0.001	0.002
98	1	1	19	2	5	0.001	0.000	0.006	0.001	0.002
99	1	1	19	2	4	0.000	0.000	0.006	0.001	0.002
100	0	0	19	2	4	0.000	0.000	0.006	0.001	0.002
Total	**2,322**	**3,001**	**3,069**	**2,532**	**2,520**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**